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PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXIX
Number 1

January, 1910

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GEORGE A. WARDLAW, Editor

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Vol. XXIX **January, 1910** No. 1

January Meeting A. I. E. E.

The two-hundred and forty-second meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York, on Friday evening, January 14, 1910, at 8 o'clock. This meeting is to be held under the auspices of the Railway Committee. Professor W. S. Franklin and Mr. Stanley S. Seyfert of Lehigh University will present a paper entitled "On the Space Economy of the Single-phase Series Motor." All members wishing to discuss this paper, either orally or by letter, should notify William McClellan, Chairman Railway Committee, 90 West Street, New York, not later than January 12, 1910.

December Meeting of the Institute

The two hundred and forty-first meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Thursday, December 16, 1909. President Stillwell presided and called the meeting to order at 8:25 p.m. The secretary announced that at the Directors' meeting held during the afternoon 74 Associates were elected, and three Associates were transferred to the grade of Member. Mr. Henry L. Doherty, of New York, presented a paper entitled "Comments on the Development and Operation of Hydro-electric Plants." The paper was discussed by Messrs. Henry G. Stott, S. E. Doane, C. T. Hutchinson, H. W. Buck, John Martin, D. B. Rushmore, W. N. Ryerson, Julian C. Smith, Calvert Townley, and Henry L. Doherty. Discussions by letter were also received from Messrs. J. F. Vaughan, W. H. Gardiner, E. C. Brown, M. H. Collbohm, James Lyman, Carl Schwartz, J. H. Wilson, and H. A. Storrs. The attendance at the meeting numbered 288, and the discussion was prolonged to a late hour.

Directors' Meeting

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at 33 West 39th Street, New York City, on Thursday, December 16, 1909. The directors present were: President Lewis B. Stillwell, New York; Past-President Henry G. Stott, New York; Vice-Presidents C. C. Chesney, Pittsfield, Mass., Bancroft Gherardi, New York, Calvert Townley, New Haven, Conn., Paul M. Lincoln, Pittsburgh, Pa.; Managers H. W. Buck, New York, Percy H. Thomas, New York, David B. Rushmore, Schenectady, N. Y., Charles W. Stone, Schenectady, N. Y., H. E. Clifford, Cambridge, Mass., A. W. Berresford, Milwaukee, Wis.,

Severn D. Sprong, New York; Secretary Ralph W. Pope, New York.

Seventy-four candidates for admission to the Institute as Associates were elected.

Three Associates were transferred to the grade of Member.

Sixty-six applicants for Student enrolment were ordered enrolled.

The Associates elected were:

ALEXANDER, F., 129 Fulton St.; res., 416 West 122nd St., New York City.

ANDERSON, MARK, Chief Engineer, Kansas City Electric Light Co., 1500 Grand Ave., Kansas City, Mo.

BACON, FREDERICK THOMAS HOWARD, Consulting Engineer, 30 Church St.; res., 126 Claremont Ave., New York City.

BAKER, CHARLES HINCKLEY, Vice-President, American Cyanamid Co., 100 Broadway, New York City.

BALDWIN, ROBERT LEE, Supervising Electrical Engineer, Burns & McDonnell, 823 Scarritt Blg., Kansas City, Mo.

BAYLIE, WALTER R., Chief Draftsman, Helios Mfg. Co., Bridesburg; res., 3419 Higbee St., Wissinoming, Philadelphia, Pa.

BIDWELL, MORRIS CHAUNCEY, Chief Electrician, Universal Motor Co., 1937 Curtis St.; Denver, Colo.

BOWES, WILLIAM RAUCHFUSS, Clayton Brothers, 127 Duane St.; res., 404 W. 116th St., New York City.

BRAGSTADT, OLE SIVERT, Technical University, Trondhjem, Norway.

CAMP, CHARLES FORSTER, Superintendent, M. B. Foster, Electric Co., 109 West 26th St., New York City.

CAREY, ALBERT H., Electrician, Black Hills Traction Company, Deadwood, S. D.

CARSON, J. PHILIP, JR., Assistant Engineer, Electric Construction Co.; res., 2025 Dayton Ave., St. Paul, Minn.

CLARK, JAMES CAMERON, Instructor in Electrical Engineering, Case School of Applied Science, Cleveland Ohio.

CLAYTOR, CHARLES HYRAM, Manager, The Tuolumne Transmission Co., and Supt., Tuolumne Electric Co., Tuolumne, Cal.

COAHRAN, JESSE MYERS, Associate Professor of Electrical Engineering, Villanova College, Villanova, Pa.

COLVIN, ALLAN DE WITT, Assistant in Physics and Electrical Engineering, Rensselaer Polytechnic Inst. Troy, N. Y.

CORRIGAN, THEODORE ELMER, Electrician, Standard Consolidated Mining Co., Bodie, Cal.

COUSINS, VOLNEY DE LOS, Instructor, Telephone Engineering, Purdue Univ. res., 400 Harvey Ave., Lafayette, Ind.

DOYLE, EDGAR DWIGHT, Student, Univ. of Illinois, Urbana; res., 706 S. 2nd St., Champaign, Ill.

DURAND, WILLIAM LEAVENWORTH, Engineer, Bureau of Standards, Washington, D. C.

EWALT, GREELY ROY, Foreman of Maintenance & Cables, Brown Telephone Co., Abilene, Kansas.

FISHEL, ANTHONY DAVID, Commercial Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

FORBICH, JULIUS J., Building Superintendent Y. M. C. A., 502 Fulton St., Brooklyn, N. Y.

FROST, ALTON M., Engineer, Moore Electrical Co.; res., Y. M. C. A. Building, Newark, N. J.

FRUEAUFF, FRANK W., Vice-President & Gen. Manager, The Denver Gas & Electric Co., Denver, Colorado.

GETZ, WILLIAM CHARLES, Electrical Assistant, United States Signal Service, 39 Whitehall St., New York City.

GLASSER, MAURICE MORDECAI, General Electric Co., Pittsfield, Mass.

HALL, WILLIAM M., Electrical Engineer, Porto Rico Power & Lt. Co.; res., Comerio Falls, Barrio Nuevo, Bayamon, P. R.

HARRISON, NOEL FAURE, Electrical Engineer, Winnipeg, Man.

Hart, Haynes Lloyd, Cadet Engineer, Westchester Lighting Co.; res., 15 Adams St., Mt. Vernon, N. Y.

Hays, James Leslie, Electrical Machinist and Draftsman, Electrical Engineering Dept., B. & O. R.R. Co., Baltimore, Md.

Henningson, Henning Henry, Salesman, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

Howe, Albert Mendel, Student and Laboratory Assistant, Rhode Island State College, Kingston, R. I.

Hull, Clarence S., Foreman, Standardizing Laboratory, General Electric Co., Union Trust Bldg., San Francisco, Cal.

Huntington, Roger Samuel, Testing & Supervising Telephone Equipment, New York Telephone Co., 114 West 89th St., New York City.

Kilner, John Saunders, Sales Department, Westinghouse Electric & Mfg. Co.; res., 335 West 78th St., N.Y. City.

Lewis, Walter W., Transformer Engineer, General Electric Co.; res., 77 Parker St., Pittsfield, Mass.

Lister, John George, Professor of Electrical Engineering, British Columbia Elec. Ry. Co's. Technical School, Vancouver, B. C.

Loeb, Albert J., Engineering Dept., Allis-Chalmers Co.; res., 232 Kewannie St., Milwaukee, Wis.

Lutz, George A., Advisory Engineer, American Circular Loom Co., Kenilworth, N. J.

MacLeod, Norman MacCallum, Telephone Engineer, Bell Tel. Co. of Penn., 11th & Filbert Sts., Philadelphia, Pa.

MacNeal, Samuel Robert, Vice-President, Bentonville Mining Co., 627 Real Estate Trust Bldg., Philadelphia, Pa.

Maddox, Wilbur Clinton, Bateman, Garrison, Maddox Co.; res., 615 South Wright St., Champaign, Ill.

Martin, Freeman Drake, Superintendent, The Fort Scott Gas & Electric Co., Fort Scott, Kansas.

Moore, Charles Ruby, Instructor in Electrical Engineering, Purdue University, Lafayette, Ind.

Morrison, William Thomas, Manager, Bronx Dist., New York Edison Co., 362 E. 149th St., New York City.

Nicoll, Robert Irwin Davis, Engineering Assistant, New York Telephone Co., 15 Dey St., New York City.

Noack, Harry Richard, President, Pierson Roeding & Co., 407 Monadnock Bldg., San Francisco, Cal.

Occleston, William H., Electrical Engineer, The Homestake Mining Co., Lead City, South Dakota.

Orsettich, Robert, Electrical Engineer, The General Elec. Co., Ltd., Wilton Works, Birmingham, Eng.

Osborne, Louis J., Representative, Fort Wayne Electric Works, 514 Kemper Building, Kansas City, Mo.

Pestel, Arthur, 557 West 124th St., New York City.

Phair, Harry Gau, Electrical Assistant United States Signal Corps, Army Building, New York City.

Porter, Harry Allen, Manager, The Robbins & Myers Co., 511 W. Jackson Blvd.; res., 7228 Coles Ave., Chicago, Ill.

Porter, Leon Walter, President, B. & C. Electrical Construction Co., 40 Charlotte St., Utica, N. Y.

Putnam, Joseph Franklin, Rockefeller Hall, Ithaca, N. Y.

Reinig, Edward Charles, Foreman at Generating Station, City of Seattle Lt. & P. Dept., North Bend, Wash.

Rhodes, Walter Kremer, Professor of Electrotechnics, Bucknell University, Lewisburg, Pa.

Rodwell, George Henry, Mechanical and Electrical Engineer, Wayne County Electric Co., Lyons; res., Clyde, N. Y.

Rose, Fred Wayland, Engineer, with Chas. L. Pillsbury; res., 1973 Carroll St., St. Paul, Minn.

Rote, John Griffin, Treasurer and Factory Manager, Gillette Safety Razor Co., 41 W. 1st St., Boston, Mass

Ryan, Thomas Francis, Chief Electrical Engineer, Guanica Centrale, Ensenada, P. R.

SCHULTE, EDWARD DELAVAN NELSON, Associate Professor of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

SEIDEL, CARLOS MARIA, Oficios 22, Havana, Cuba.

SHARP, HARRY LYMAN, Meter Inspector, Niagara, Lockport & Ontario P. Co., Fidelity Bldg., Buffalo, N. Y.

SMITH, JAY L., Electrical Engineer, St. Joseph Railway, Light, Heat & Power Co.; res., 1510 Lafayette St., St. Joseph, Mo.

STANLEY, ERWIN, Commercial Engineer, General Electric Company, Pittsfield, Mass.

SWEET, FELIX L., Superintendent, Texas-Mexican Electric Light & Power Co., Eagle Pass, Texas.

TERRELL, WENDELL PHILLIPS, Professor of Mechanics, Prairie View State Normal & Industrial College, Prairie View, Texas.

TURNER, CLAUDE VERNON, Superintendent, Laurel Creek Electric Co., Lawton, West Virginia.

VOGEL, ABRAHAM, Electrical Engineer, Mitchell & Mussigbrod, Warm Springs Mont.

WHALEY, W. JUNIUS, Salesman, The Wesco Supply Co.; res., 20 South 20th St., Birmingham, Ala.

WIGGERT, JOHN F., Assistant Electrician, Homestake Mining Co.; res., 312 Sawyer St., Lead, S. D.

WILLIAMS, WYNANT JAMES, Instructor in Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Total, 74.

The Associates transferred to the grade of Member were:

CHARLES WILLIAM RICKER, Electrical Engineer, Cleveland Construction Company and the Warren-Bicknell Company, Cleveland, O.

HERMAN L. WALLAU, Electrical Engineer, Cleveland Electric Illuminating Company, Cleveland, O.

HOWARD L. BEACH, Electrical Engineer, Penna. Coal and Coke Company, Cresson, Pa.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before January 25, 1910.

9039 Fulton, R. A., Cleveland, O.
9040 Gilles, R. L., St. Paul, Minn.
9041 Sulzer, W., Pittsburg, Pa.
9042 Moyer, H. C., W. Lynn, Mass.
9043 Hill, J. E., Iowa City, Ia.
9044 Hulett, G. A., Princeton, N. J.
9045 Jones, B., Jr., New York City.
9046 Jones, W. W., New York City.
9047 Pope, H. S., Boston, Mass.
9048 Thomas, F. B., Telluride, Colo.
9049 Ulmer, M., Mexico City, Mex.
9050 Anthony, R. B., Pittsburg, Pa.
9051 Johnson, W. S., Los Angeles, Cal.
9052 Peaslee, W. D. A., Stanford University, Cal.
9053 Struthers, H. H., New York City.
9054 Anderson, R. T., Passaic, N. J.
9055 Badeau, H. U., Bridgeport, Conn.
9056 Cody, F. L., Cobalt, Ont.
9057 Nanheim, S. A., New York City.
9058 Swigert, W. E., Passaic, N. J.
9059 Barnett, J. W., Honduras, C. A.
9060 Christiansen, C. E., Toledo, Ore.
9061 Connette, E. G., New York City.
9062 Jensen, H., Bangkok, Siam.
9063 Shearer, C. W., New York City.
9064 Traver, O. C., Honduras, C. A.
9065 Amott, T. F., Charleston, Wash.
9066 Nelson, A. A., Butte, Mont.
9067 Robinson, W. W. H., Jr., N. Y. C.
9068 Sampson, H. L., Chicago, Ill.
9069 Whitehead, J. J., New York City.
9070 Shedd, H. E., Oakland, Cal.
9071 Dewey, F. S., Davenport, Iowa.
9072 Howard, A. J., Medina, N. Y.
9073 Perrin, L. M., San Francisco, Cal.
9074 Rees, H. P., Porto Alegre, Brazil.
9075 Shinn, W. C., Lincoln, Neb.
9076 Stockbridge, G. H., Los Angeles, Cal.
9077 Billings, W. C., Bangor, Me.
9078 Cass, R. M., Indianapolis, Ind.

9079 Kidd, J. W., College Station, Tex.
9080 Marguerre, F., Christiania, Norway.
9081 Brown, E. C., Washington, D. C.
9082 Commeford, J. W., Jr., Toronto, Ont.
9083 Flood, Henry, Jr., Newburgh, N.Y.
9084 Jones, H. McR., Ensenada, P. R.
9085 Taylor, J. B., New York City.
9086 Wainwright, W. S. K., N. Y. C.
9087 Collingham, R. H., Rugby, Eng.
9088 Kennedy, A., Jr., Schenectady, N.Y.
9089 Franz, Joseph, Lenox, Mass.
9090 Hawkins, A. V., Washington, D. C.
9091 McLaughlin, J.C., Washington, D.C.
9092 Perrine, W. J., Vincennes, Ind.
9093 Whitehead, R. H., Chicago, Ill.
9094 Allen, J. S., Lake Geneva, Wis.
9095 Grove, W. H., Philadelphia, Pa.
9096 Hesch, H. C., Provo, Utah.
9097 Kahler, C. P., Salt Lake City Utah.
9098 Owens, J. W., New York City.
9099 Parker, C. H., Boston, Mass.
9100 Patten, H. C., Dorchester, Mass.
9001 Sinsabaugh, F. M., Carrollton, Ill.
9102 Wolcott, K. O., Hawthorne, Ill.
9103 Wright, W. P., Anderson, S. C.
9104 Goldberg, M. M., Ithaca, N. Y.
9105 Ball, A. W., Texarkana, Tex.
9106 Jeter, G. G., Urbana, Ill.
9107 Adams, E. D., New York City.
9108 Carley, R. F., Galesburg, Ill.
9109 von Blucher, G.A., San Antonio, Tex.

Total, 71.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at a meeting held on December 10, 1909. Any objection to these transfers should be filed at once with the secretary.

Barton R. Shover, Electrical Engineer, Indiana Steel Company, Gary, Indiana.

Morton Arendt, Instructor in Electrical Engineering, Columbia University, New York.

Putnam A. Bates, Consulting Electrical Engineer, 2 Rector Street, New York.

Nominations

For the purpose of giving information to the membership in connection with future nominations for officers of the Institute, after the distribution of the nomination forms, in February, the following by-law was adopted by the Board of Directors November 13, 1908:

Sec. 18. For the guidance of members in the selection of nominees for the annual election there shall be published in the January and February Proceedings, each year, a summary of the nomination votes of the preceding year containing the names of all persons having received at least three per cent of the entire number of nomination votes cast, and also the names of all directors not included in this list and of ex-Vice-Presidents and Managers who have held office at any time during the preceding five years.

In compliance with this by-law the following list has been compiled:

General Proposal List, April, 1909

Note: Names printed in italics indicate that these officers were elected and their terms began on August 1, 1909.

FOR PRESIDENT

L. B. Stillwell	722
Ralph D. Mershon	39
J. G. White	38

FOR VICE-PRESIDENTS

J. J. Carty	471
Paul M. Lincoln	265
Paul Spencer	203
A. M. Schoen	178
E. J. Berg	171
A. M. Hunt	111
Ralph D. Mershon	66
J. P. Jackson	60
W. S. Murray	40

FOR MANAGERS

A. W. Berresford	587
W. S. Murray	426
H. H. Norris	243
S. D. Sprong	143
H. B. Smith	139
Henry Floy	105
N. W. Storer	45
W. S. Rugg	41
J. F. Stevens	40

FOR TREASURER

George A. Hamilton	853

FOR SECRETARY

Ralph W. Pope	858
F. L. Hutchinson	59

PRESENT DIRECTORS NOT INCLUDED IN ABOVE GROUPS

Morgan Brooks
Harold W. Buck
Wm. G. Carlton
Cummings C. Chesney
H. E. Clifford
Louis A. Ferguson
Bancroft Gherardi
Benjamin G. Lamme
David B. Rushmore
Charles W. Stone
Henry G. Stott
Percy H. Thomas
Calvert Townley

EX-VICE-PRESIDENTS AND MANAGERS WHO HAVE HELD OFFICE DURING THE LAST FIVE YEARS NOT INCLUDED IN ABOVE GROUPS

A. H. Armstrong
W. S. Barstow
Frank G. Baum
Charles L. Clarke
Gano Dunn
Charles L. Edgar
W. C. L. Eglin
W. E. Goldsborough
H. H. Humphrey
C. O. Mailloux
Samuel Reber
Calvin W. Rice
George F. Sever
Charles A. Terry
Schuyler S. Wheeler
Townsend Wolcott

1910 Year Book

A new edition of the Institute Year Book will be ready for distribution early in January. The contents include: Lists of Officers; Committees; Sections and Branches, their location and officers; Alphabetical and Geographical Lists of Members and Associates; Constitution; By-Laws; Report of Board of Directors for year ending April 30, 1909, and the Standardization Rules; also, for the use of non-members, general information regarding the objects, scope, and work of the Institute.

As practically the entire contents of the book, except the revised lists of members, have appeared in the PROCEEDINGS, copies will be mailed to the membership only upon request; the book will be used principally in connection with the work of the Institute Committees. Any Member or Associate may, however, obtain a copy upon application, by mail or in person, to the Secretary's office.

Joint Meeting at Boston, Mass. January 21, 1910

On January 21, 1910 the American Society of Mechanical Engineers, Boston Society of Civil Engineers, and the Boston Section of the American Institute of Electrical Engineers will hold a joint meeting in Boston, Mass. to discuss the subject of a united engineering building in Boston. There will also be an address on the U. S. battleship North Dakota, and speeches by the presidents of the respective engineering societies.

American Institute of Chemical Engineers

The second annual meeting of this society was held at the Hotel Walton, Philadelphia, Pa., December 8–10, 1909. E. R. Taylor of Penn Yan, N. Y., presented a paper entitled "Electric Furnace for the Smelting of Iron Ore." The following officers were elected.

Chas. F. McKenna, president; F. W. Frerichs, first vice-president; Edward G. Acheson, second vice-president; Eugene Haanel, third vice-president; John C. Olsen, secretary; William M. Booth, treasurer; Henry S. Renaud, auditor; Geo. B. Adamson, David Wesson, Edward Gudeman, directors for one year; Ludwig Reuter, Thorn Smith, H. F. Brown, directors for two years; William M. Grosvenor, Richard K. Meade, S. P. Sadtler, directors for three years.

Massachusetts Institute of Technology

The requirements for the degrees of doctor of engineering and doctor of philosophy at this institution have now been made substantially equivalent, as far as the period of study and the candidates' attainments are concerned. The Executive Committee has voted to maintain two Austin research fellowships carrying a grant of $500 each and the remission of tuition fees; these are now to be open equally to candidates

for the two degrees mentioned above. Fifteen other graduate scholarships and fellowships are also maintained.

During the present year seventeen candidates for advanced degrees have been awarded fellowships or graduate scholarships. Two of these were for the encouragement of advanced study in Germany by Technology graduates and the remainder for the encouragement of advanced study in the Institute.

The advanced instruction in the theory of alternating currents and electrical transmission of power accompanied by advanced research is continued this year under the direction of Dr. Harold Pender. Other work carried on by the department for the benefit of students desiring to do original research or who are studying with a view to obtaining advanced degrees, include the lectures and investigations under Professor Jackson on the organization and administration of public service corporations, and instruction in the designing of electric plants by Professor Wickenden. Various researches are now going on in the electrical engineering laboratories in connection with this graduate work.

Sections and Branches

University of Arkansas Branch

The semi-monthly meeting of the University of Arkansas Branch was held on November 18, 1909. Mr. H. Herbert read the Institute paper on "The Electric System of the Great Northern Railway Company at Cascade Tunnel." The paper was discussed by Chairman Stelzner, who is familiar with the equipment on this system. Professor A. A. Steel then presented a paper on "Electric Wiring in Mines", speaking from many years of personal experience in mining engineering. The last paper read was contributed by Mr. G. C. Baker, a former student, who is now first-class electrician on the U. S. S. Virginia. It described the many applications of electricity in the U. S. Navy, including wireless telephony and telegraphy, lighting, signaling, and the handling of big guns by electricity. There was an attendance of 33 members.

At the meeting of the Branch held on December 2, Mr. F. S. White presented an original paper on the "Magnetic Circuit", based on the paper read by Mr. Carl Hering before the Philadelphia Section on February 10, 1908, on "An Imperfection in the Usual Statement of the Fundamental Law of Electromagnetic Induction." The following five-minute papers were read and discussed; "Current News and Notes", by Mr. L. R. Cole; "Illumination", by Mr. D. A. Stover; "Recent Installations", by Mr. P. L. Mardis; "New Apparatus and Appliances", by Mr. H. E. Eason.

Baltimore Section

The November meeting of the Baltimore Section was held in the physics laboratory of the Johns Hopkins University. Mr. L. F. Deming, district engineer of the General Electric Company, gave a paper on "The Relation of Synchronous Apparatus to Power-Factor Adjustment." Mr. Deming showed the necessity for such adjustment, and how it is usually best obtained by the use of synchronous motors. The paper was discussed by Messrs. A. S. Loizeaux, Carroll Thomas, and J. B. Whitehead.

Boston Section

Dr. Louis Bell addressed the members of the Boston Section at its regular monthly meeting held in the auditorium of the Edison Building, Boston, on November 17, 1909. Dr. Bell's subject was "The Economics of Modern Lighting." About 75 members were present, and an interesting discussion followed. Among those taking part were: Messrs. Wickenden, Hussey, Kennelly, Neall, Jackson, Clark, Lewis, Puffer, and Palmer.

A special meeting of the Section was held at Harvard University on De-

cember 4, 1909. The members met about 4:00 p.m. at Pierce Hall, where guides under the direction of Professors A. E. Kennelly and C. A. Adams escorted them to points of interest in the engineering laboratories and other parts of the university. At 6:30 p.m. they met for an informal dinner in Memorial Hall, after which Dr. G. W. Pierce delivered a lecture on "Measurements of the Wave Length and Frequency of Electromagnetic Waves", which was illustrated by apparatus and experiments. About 85 members were present at the dinner, and about 100 at the lecture.

Case School Branch

The Branch at the Case School of Applied Science, Cleveland, Ohio, was re-organized for the year 1909–10 on October 13, 1909, and the following officers were elected: Chairman, C. N. Weems; secretary, S. G. Hibben; treasurer, E. A. Seymour, executive committee, W. R. Waggoner. A number of meetings were subsequently held in October, and the following papers presented: "High-Tension Transformers", by Mr. Burchfield; "Substation Practice", by Mr. Francy; "Electricity and Conservation of Matter", by Mr. Denman; "Auxiliary Poles of Direct-Current Machines", by Mr. Goldberg; "Testing of Transformer Steel", by Mr. Goodman.

On November 10, Mr. H. A. Hackenberg read a paper on "Wireless Telephony", in which he described the Poulsen method of obtaining high-frequencies from alternators and arcs, and gave illustrations of transmitter and receiver connections. Some of the points taken up in the discussion which ensued were the heat effects in charging and discharging of plates, ionization of gases, and multiplex systems of wireless telephony.

At the meeting held on November 17 a paper was presented by Secretary S. G. Hibben, dealing with electric heating and heating appliances. Mr. Hibben gave some data on relative costs in connection with electric heating, and described some interesting personal experiments with immersion water-heaters and kitchen appliances.

Chicago Section

A successful joint meeting of the Chicago Section with the Electrical Section of the Western Society, of Engineers was held on Tuesday evening, November 16, 1909, and nearly 800 members and their friends gathered to hear a lecture by Dr. C. P. Steinmetz on "The Law of the Conservation of Energy." Mr. W. L. Abbott, chairman of the joint committee, resigned the chair in favor of Mr. Bion J. Arnold as the one best entitled to preside at the joint meeting, owing to the fact of his being a past-president of both organizations. Mr. Arnold introduced Mr. Ralph W. Pope, secretary of the Institute, who gave a brief description of his Pacific Coast tour. Dr. Steinmetz was then announced, and his lecture was received with much enthusiasm. Past-president Louis A. Ferguson was also at the meeting.

University of Cincinnati Branch

A special meeting of the University of Cincinnati Branch was held on November 24, 1909, for the purpose of electing officers. The meeting was the first of the season. Mr. C. R. Wylie was reëlected chairman, and Mr. Ralph B. Kersay was elected secretary. A committee was appointed to recommend a suitable date for holding regular meetings.

Cleveland Section

The Cleveland Section held its regular meeting in the Case School of Applied Science on November 15, 1909. The subject discussed was "Voltage Regulation." Chairman H. L. Wallau opened the meeting with an introductory talk on the requirements of voltage regulation on light and power circuits, and the effects of poor regulation from the con-

sumer's and central station standpoint. As Mr. Wallau has had to maintain almost perfect regulation on about 60 square miles 'of overhead construction, his talk was interesting. Mr. Martignone, of the General Electric Company, presented a paper on " The Tirrell Regulator ". It was illustrated by lantern slides. The next paper, dealing with alternating feeder regulators, was read by Mr. F. F. Rossman, of the Westinghouse Electric and Manufacturing Company. Mr. H. L. Wallau then gave a general description of the regulation apparatus and methods in use by the Cleveland Electric Illuminating Company. Mr. C. W. Ricker and Professor H. B. Dates discussed some of the ill effects of close regulation under suddenly varying loads, such as in interurban railway. plants. The meeting was one of the most successful held by the Section, and the discussion was prolonged to a late hour.

University of Colorado Branch

The regular meeting of this Branch was held on October 20, 1909, with 43 members in attendance. A paper was read by Mr. Pine, on " Experience with Induction Motors." Mr. A. L. Johnstone also presented a paper in which he described the transmission lines of the Telluride Power Company.

The next meeting was held on November 13, 1909. Mr. A. R. Thorson, testman for the Northern Colorado Power Company, gave a talk on " Integrating Wattmeters."

Fort Wayne Section

The regular meeting of the Fort Wayne Section was postponed from the usual date of the second Thursday of the month to Monday, November 22, 1909, in order that the members could welcome Secretary Ralph W. Pope, who had arranged to be present at a meeting of the Section on the latter date. After an informal dinner at the Anthony Wayne Club, the meeting was called to order and Chairman E. A. Wagner introduced Mr. Pope, who after a brief description of his recent trips to the West, spoke on the work of the various Sections, and the increase in the facilities at Institute headquarters for further coöperation with the Sections.

At the conclusion of Mr. Pope's remarks, the paper of the evening, entitled " Current Transformers ", was read by Mr. P. C. Morganthaler, meter engineer of the Fort Wayne Electric Works. The paper dealt with the effect of current transformers on the instruments with which they are in circuit, the particular instrument under consideration being the watt-hour meter type, with special significance to the relation existing between the various components of the current and potential circuits, especially as the angle of lag developed from the exciting current of the transformer may affect the accuracy of the meters. Diagrams were shown to illustrate how any change of the power-factor of the secondary load would likewise affect the ratio and phase angle. The paper was discussed by Messrs. A. L. Hadley, E. A. Wagner, T. W. Behan and P. H. Hazelton. Mr. Pope made a short closing address in which he expressed his regret that the Section could not have had as guests the same evening President Stillwell and Dr. C. P. Steinmetz, both of whom he had hoped could be present.

Iowa State College Branch

In the expectation of having as a guest and speaker of the evening, Secretary Ralph W. Pope, a meeting of the Iowa State College Branch was held on November 17, 1909, at which 71 members were present. As a result of a railroad wreck, Mr. Pope did not arrive until the following morning. The evening was devoted to an abstract of Dr. Hutchinson's Institute paper, " The Electric System of the Great Northern Railway Company at Cascade Tunnel ", by Mr. M. W. Pullen. On his arrival in the morning Mr. Pope met the senior electrical engi-

neers, and a very pleasant hour was spent, in the course of which he recounted many humorous anecdotes and incidents of his recent trip to the Pacific Coast. Owing to its location in a state where industrial development has only recently been making rapid progress, some difficulty has been experienced in securing the services of prominent engineers to inspire enthusiasm in the work of the Branch, so the visit of Secretary Pope was keenly appreciated.

Ithaca Section

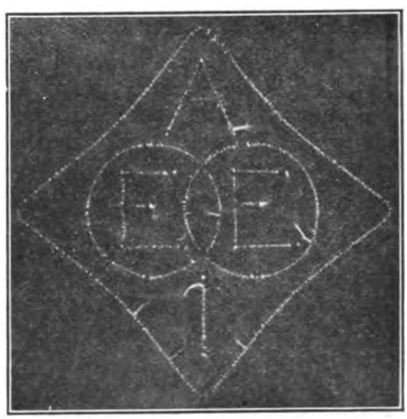
At the regular monthly meeting of the Ithaca Section on November 19, 1909, Mr. W. T. Damon presented a paper on "Induction Motors Versus Series Motors for Railway Work." Eighty-eight members and students were present. The paper was intended to familiarize the younger members with the principles governing the operation of the apparatus used in the installation treated of in the paper. Mr. Damon first explained the principles of the induction motor and discussed its characteristics with especial reference to its application to traction work. He discussed the series direct-current and series alternating-current motors, and then compared the characteristics of these with the characteristics of the induction motor.

The main subject of the evening was the Institute paper by Dr. Cary T. Hutchinson, presented at the November meeting, on "The Electric System of the Great Northern Railway at Cascade Tunnel." This was abstracted by Mr. T. E. Orbison, who confined his remarks to the special and unusual features of the installation.

Those taking part in the discussion following the papers were: Messrs. Bedell, Norris, Putnam, Dennison, Cornell, Gage, and Kent.

On December 3, 1909, Professor G. S. Macomber gave an illustrated address on the subject of "Some Applications of the Cathode Ray Oscillograph." The apparatus used to illustrate the lecture was developed by Professor H. J. Ryan some years ago, and employed by him at that time in determining atmospheric losses on high-tension transmission lines. Professor Macomber was Professor Ryan's assistant when these experiments were made. He reviewed the development of the cathode tube and its applications by Professor Ryan. After some discussion of the subject the members were given an opportunity to examine the apparatus and observe the experiments at close range.

A rather unique reproduction of the Institute emblem, devised by some of the ingenious members of the Ithaca Section, was used at a recent meeting. It was in the form of a corona plate, and it aroused a great deal of interest. As some of the members of other Sections and Branches might be interested, it has been reproduced from a photograph and printed on this page.



Kansas State Agricultural College Branch

The Kansas State Agricultural College Branch held its first meeting of the season on September 24, 1909, in the physical science hall, with 16 members present, and Mr. Roy Wilkins presiding. Mr. A. Strong was elected treasurer, and Messrs. H. T. Morris, H. E. Hershey,

G. R. Bushey, and C. Q. Ward, members of the executive committee.

On October 5 fifty-five members made a visit of inspection to the Manhattan Electric Light and Power Company's plant, Manhattan, Kansas, where Mr. C. Stiner, erecting engineer, demonstrated the operation of a newly installed steam turbine.

At the meeting held on November 2 Mr. Kirk Logan reviewed Mr. J. B. Taylor's Institute paper on " Telephone and Telegraph Systems as Affected by Alternating-Current Lines."

University of Kansas Branch

The regular meeting of this Branch was held on November 3, 1909. The program consisted of the following talks: " The Practical Operation of Gas Engines ", by Mr. R. L. Ponsler; " How a 550-Volt Generator was Used on 220-Volt Mains ", by Mr. G. W. Russell; " Motor Troubles and Their Remedies ", by Mr. M. D. Leslie. All of the speakers were members of the senior class.

Mr. L. E. Mason was to have been the speaker at the meeting of the Branch held on November 17, 1909, but through a misunderstanding as to the date of the meeting, he was not present. Messrs. C. W. Nystrom and C. F. Hanson reviewed and discussed some of the leading topics in recent engineering publications.

Los Angeles Section

This Section held a regular meeting on Tuesday, November 23, 1909, at Blanchard Hall. There was a total attendance of 34 members and 32 visitors. After the appointment by Chairman Lighthipe of an entertainment committee and a membership committee, the paper for the evening, entitled " High-Tension Switches and Switching ", was presented by Mr. J. N. Kelman. Among those who took part in the discussion were, Messrs. O. H. Ensign, E. F. Scattergood, E. R. Northmore, R. W. Shoemaker, R. H. Manahan, E. Y. Porter, and A. C. Jewett. Mr. Jewett gave some interesting reminiscences of " Seven Years in India." Mr. Ensign, electrical and mechanical engineer of the United States Reclamation Service, gave an interesting account of the development of switches in Southern California in the early days of the alternating current.

Minnesota Section

The first meeting of the Minnesota Section for this season was held on November 18, 1909, at the Transportation Club, St. Paul. The subject of the meeting was Dr. Hutchinson's Institute paper on the Cascade Tunnel electrification. Mr. Ralph W. Pope, secretary of the Institute, was to have been the guest at this meeting, but a train wreck delayed his arrival until after the meeting was adjourned. A number of steam railway men were present and contributed to the discussion. An informal dinner preceded the meeting. The total attendance numbered 60 members and visitors.

University of Missouri Branch

The members of the University of Missouri Branch met at the home of Professor Alan E. Flowers, on Allen Place, Columbia, Mo., October 22, 1909. It was the first meeting held by the Branch this season, and there was a total attendance of 18 members. There was a brief business session at which an executive committee of three was appointed. Professor Flowers then addressed the members, outlining the purposes and scope of the Institute, and urging that as many students as possible become members of the Branch. A social hour followed, during which the members were entertained by Professor and Mrs. Flowers, assisted by Miss Allen. A series of college songs contributed much to the pleasure of the evening.

The next meeting of the Branch was held in the Association Building on November 15, 1909, with Professor H. B. Shaw presiding. Secretary H. D. Carpenter having expressed his desire to be relieved from the office of secretary, the chairman was authorized to appoint his successor, and he selected Professor A. E. Flowers. After an informal discussion as to suitable subjects, for subsequent meetings, the executive committee was requested to arrange for papers on conservation of natural resources, and on the local light and water system. Mr. J. B. Taylor's paper on "Telephone and Telegraph Systems as Affected by Alternating-Current Lines" was then reviewed and discussed.

The third meeting was held on November 29, 1909. Thirty-two members were present. Professor Shaw reviewed the recent history of the conservation movement. Professor Rodhouse gave a description of the work being done by the United States Reclamation Service. Messrs. Hill and Andrews presented data on the water supply of the country. Messrs. Miller and Mann gave important facts on the treatment of forests in the United States and abroad. Messrs. McVey and Whitlow discussed fuel resources, and the program concluded with a discussion by Messrs. Kobrock and Stapf on oil and gas resources.

Dr. Cary T. Hutchinson's paper on the Great Northern Railway Company's electrification at Cascade Tunnel was the subject of discussion at the meeting of the Branch held on December 10, 1909. The various phases discussed were: General conditions, and advantages and disadvantages of electric traction, by Mr. W. S. Hill; choice of type and design of locomotive, by E. A. Roehry; generating station, by Mr. A. R. Oliver; transmission system, by Mr. C. F. Schulze. Professor Shaw spoke of the various steps in the electrification of railways. There was a total attendance of 24 members.

Ohio State University

The Ohio State University held a meeting on December 8, 1909. Professor Lord gave an address on "Technical Training for an Electrical Engineer." The Branch will give an electrical show and banquet in February.

Oregon State Agricultural College Branch

The November meeting of the Oregon State Agricultural College Branch was held on November 23, 1909. Mr. J. B. Taylor's paper on "Telegraph and Telephone Systems as Affected by Alternating-Current Lines" was reviewed by Professor T. M. Gardner, the review being preceded by a brief history of the telephone and telegraph in America.

At the business meeting following the close of the discussion it was decided that the Branch shall take up a systematic study of some electrical engineering subjects not at present included in the curriculum of the college. Wireless telegraphy and telephony, applied electrochemistry, and electric furnaces were suggested by different members. The majority decided in favor of electrochemistry, and this subject will be taken up as a part of each program at future meetings.

Pittsfield Section

The second meeting of the Pittsfield Section was held in the Hotel Wendell on November 23, 1909. Dr. M. W. Franklin, of Schenectady, N. Y., delivered an address on "The Electric Fixation of Nitrogen." There was an attendance of 86 members at the meeting.

Portland Section

The regular monthly meeting of the Portland Section was held on Tuesday evening, November 16, 1909. In the absence of Chairman Coldwell, Mr. Paul Lebenbaum, formerly a member of the

San Francisco Section, was called upon to preside. A paper on "Illuminating Engineering from the Central Station Standpoint" was read by Mr. W. M. Hamilton, The discussion brought out several points in the system of lighting that is to be adopted in Portland's new Electric Building.

PURDUE UNIVERSITY BRANCH

Professor J. W. Esterline addressed the members of the Purdue University Branch at a meeting held on October 26, 1909, on the subject of "Outdoor Illumination." Over a hundred members were present. Professor Esterline spoke from personal experience as consulting engineer on a number of important lighting installations. A summary of the address is as follows: Years ago many city streets were lighted by open arc lamps. These lamps were given a nominal high candle power, and rarely met the requirements. A number of objections made the open arc lamp impractical. One of the greatest disadvantages was that although plenty of light was given off it was so poorly diffused that it failed to be effective. Around the lamp the light was so bright as to be blinding, but the rays were not projected a sufficient distance properly to illuminate the space between lamps. Sleet, snow, and insects were a frequent cause of trouble. Later the enclosed arc light was developed. When this lamp was first being tried an investigation of its efficiency was made under the supervision of Professor Matthews, of Purdue University. It failed to prove a success. The distribution of light was not satisfactory since by the alternating current the arc was inverted and the rays of light directed upward much of the time. The most recent development, the metallic arc, was originated about three years ago. This is now recognized as the most economical means of lighting city streets. The source of light is a flame between the electrodes. The upper electrode is a metallic tube filled with chemicals which give the light a strong white effect. Immediately above the upper arc is a porcelain shade which reflects the light. The city of Lafayette (Indiana) is lighted by this type of lamp, and according to the present schedule more economically than many other cities in the United States, the cost being about $38.00 per year per lamp. The tungsten lamp has proved more economical in small cities and in a residential districts of larger cities. It is generally recognized in street lighting that it is much better thoroughly to light the streets when required than to have a lesser number of lamps burning all the time. Many cities regulate their lighting by the moonlight schedule. In general, 3,600 to 4,000 hours per year may be calculated as sufficient for lighting a city. Many curves were shown illustrating the distribution of light from different types of arc lamps. A general discussion followed the address.

At the meeting of the telephone section of the Branch held on November 3, 1909, Professor C. M. Smith gave a lecture on "Wireless Telegraphy and Telephony." One hundred and twenty-two members and visitors were present. The lecture was illustrated by diagrams and some demonstrations were made by apparatus set up for the purpose. Professor Smith introduced the subject with a brief resumé in which he pointed out the important place which must be assigned to the fundamental researches of Faraday, Maxwell, Hertz, Kelvin, and Lodge. He reviewed the basic principles of wave-motion and made a comparison between the short ether waves which manifest themselves to the eye as light, and the long waves utilized in wireless telegraphy. He discussed the phenomena of standing waves, accompanying his remarks with illustrations by means of a vertical steel wire thrown into segmental vibrations. The phenomena of other wave-motion and the various devices for generating and detecting electric waves were described. In connection with modern receiving

apparatus, Professor Smith dwelt on the growing importance of the property of unilateral conductivity as exhibited by carborundum and other crystals, making them useful as rectifiers of alternating currents. He then proceeded to give an account of the progress in wireless development. Before 1896 the distance through which a message could be sent by means of the wireless system was less than half a mile. In the succeeding two years this was increased by Marconi to 12 miles. A year later a message was sent across the English Channel, and finally, in 1900, across the Atlantic Ocean. So rapidly has the wireless field developed that since that time almost every ocean-going vessel is equipped with wireless telegraph apparatus. Perhaps the longest distance over which a message has been sent is from Paris to a point in Canada, a distance of 4,000 miles. In conclusion Professor Smith mentioned some of the difficult problems which must be solved before wireless communication can be regarded as successful. The ability to obtain uniform undamped waves with equal amplitude and the different designs of high-frequency alternators were discussed. As a most efficient means for producing high-frequency undamped oscillations, he gave a description and demonstration with the Duddell singing arc.

Another meeting of the telephone section was held on November 16, 1909, at which Mr. V. D. Cousins, of the telephone engineering department of the university, delivered a lecture on "Telephone Maintenance."

St. Louis Section

The November meeting of the St. Louis Section was held in the rooms of the Engineers' Club on November 24, 1909. A paper was read by Mr. F. W. L. Peebles on the subject, "A Brief Resumé of the Present Aspect of the Science of X-ray Energy." Mr. Peebles spoke of the design of induction coils used in X-ray work, and the design of the tubes for the best effects. The development of the negatives was discussed at some length, which was followed by a short discussion on the physiological effects of X-rays.

San Francisco Section

The members of the San Francisco Section were addressed by Mr. Herman Schussler, chief engineer of the Spring Valley Water Company, at a meeting held on November 19, 1909, on "Some Engineering Features of the Spring Valley Water System." As the city of San Francisco is somewhat peculiarly situated in respect to its water supply, the subject proved of sufficient interest to attract a large number of members. The Spring Valley Water Company, which supplies San Francisco, is perhaps one of the most interesting systems of its kind. The San Mateo Hills, distant from San Francisco, about 25 miles, form a natural reservoir of enormous dimensions, which is fed by a watershed. Another source of supply is the natural filter beds, some 50 miles from San Francisco, and across the bay. This is also a part of the Spring Valley system. Mr. Schussler's paper also dealt with the great Crystal Springs Dam, which is the second highest dam in the world, the water supply to the city from the various systems, and the construction of the four 16-inch pipes laid at the bottom of San Francisco Bay for a distance of four miles. The paper was illustrated with diagrams and lantern slides.

Schenectady Section

The second meeting of the Schenectady Section was held on Tuesday evening, November 16, 1909, and about 300 members were present. Mr. A. L. Rohrer, electrical superintendent of the General Electric Company, delivered an informal address on "The Student Engineer and His Opportunities." The object of this meeting was to arouse more enthusiasm among the young engineers in Schenectady and

its immediate vicinity, and to point out to them opportunities open not only in engineering, but also in commercial work. Mr. Rohrer gave a brief history of the testing department of the General Electric Company, and told of the work done from 1884 to the present time. He spoke of the many advantages to be derived from a training in this department, and mentioned some of the positions occupied later in life by young men who have been in this department.

Mr. Baldwin, of the foreign department of the General Electric Company, Mr. F. W. Wilcox, of Harrison, N. J., and Mr. F. H. Gale, gave short talks on the same subject.

On Tuesday evening, November 30, Dr. E. Mac D. Stanton read a paper on "The Cause of Death from Electric Shock by Commercial Electric Current and the Treatment of Shock." Dr. Stanton has devoted much time to this subject and has conducted experiments on the effects of electric shock upon animals. His conclusions as to the cause of death may be grouped under three heads: First, actual destruction of the tissues, secondly, interference with the heart's action; thirdly, paralysis of the respiratory centers. He said that resuscitation is frequently possible by the use of high-frequency currents, if the electricity is applied before the blood pressure is spent. The address was illustrated by several diagrams showing the heart action on the application of current to an animal pronounced dead. The diagrams showed that the blood pressure rose almost to normal, and it was stated that where resuscitation was not possible in such cases it was primarily due to the fact that the brain had been too long without nourishment All of the members of the Schenectady Medical Society had been invited to attend the meeting, and an interesting discussion followed. There was a total attendance of about 600 members and visitors.

Seattle Section

In the absence of Chairman Harisberger, Professor C. E. Magnussen presided at the meeting of the Seattle Section held on November 20, 1909. As a result of the efforts of a committee which had been appointed in October for the purpose of promoting interest in the meetings, there was a very good attendance. Some correspondence was read suggesting a review of the Institute paper by Dr. Hutchinson on "The Electric System of the Great Northern Railway Company at Cascade Tunnel," and it was announced that a paper on the subject would be presented in the near future by Mr. R. Beeuwkes. Professor Magnussen then introduced Mr. Alexander S. Moody, who read a paper on "A 1200-Volt Railway System." The paper treated of the present status and possible future of the direct-current motor, and gave data in support of the contention that the direct-current system for interurban traffic is equal to the single-phase or alternating-current system. Mr. Moody admitted that the item of sub-station equipment for the direct-current system was heavier, but claimed that the disparity is offset in many cases by the more frequent repairs necessary on the single-phase motors and equipment. In the discussion which followed, both systems were advocated. Among those participating in the discussion were: Messrs. Arms, Loew, Magnusson, Hoskins and Moore.

Stanford University Branch

The members of the Stanford University Branch met at Encena Hall on November 23, 1909. A communication from the Institute Committee on Industrial Power was read and discussed, and it was decided to devote a meeting next March to this subject. Professor S. B. Charters read a paper on "Some Phases of Transformer Regulation" prepared by himself and Mr. W. A. Hillebrand, and presented at the October meeting of the San Francisco Section This paper is printed in Section II of this issue of the PROCEEDINGS.

Syracuse University Branch

The monthly meeting of the Syracuse University Branch was held on December 9, 1909. Professor W. P. Graham abstracted Mr. J. B. Taylor's paper on "Telegraph and Telephone Systems as Affected by Alternating-Current Lines," and discussed certain aspects of the subject.

Toledo Section

The meeting of the Toledo Section scheduled for December was held a week earlier than usual, on November 27, 1909, in order that the members could have an opportunity to hear an address by Mr. E. J. Bechtel, consulting electrical engineer, of New York, on "Factors Entering Into Cost of Electric Current." Mr. Bechtel gave prominence to problems of the boiler room, owing to the possibilities of increasing the efficiency at this point. An important consideration is to locate the power station where an ample supply of water is available. Next in importance is economy in fuel. Whether the installation of accessories is likely to prove profitable depends upon the size of the plant and the regularity of its operation. Other factors of cost to be kept in mind, in addition to the initial investment, are interest, depreciation, and taxes. With a plant supplying current, the regularity with which it is taken by the consumer is an important feature. The final cost of supplying current at the rate of one hour per day is 17 cents per kilowatt-hour, while if it is taken for 24 hours per day, the cost may be reduced to as low as two cents per kilowatt-hour.

Toronto Section

The Toronto Section held its regular monthly meeting on November 19, 1909. Prior to the meeting, 30 members met for dinner at the St. Charles Cafe. Messrs. G. S. Merrill and J. S. Hoit, both of the National Electric Lamp Association, Cleveland, Ohio, the speakers for the evening, were guests at the dinner. The meeting was held at the Engineers' Club, with Mr. H. W. Price in the chair. After a few preliminary remarks Mr. Price introduced the speakers. The subject of Mr. Merrill's paper was "Various Aspects of the Tungsten Lamp", and that of Mr. Hoit's, "The Tungsten Lamp for Street Lighting."

Mr. Merrill described in detail the methods of developing manufacturing, and testing of tungsten lamps, illustrating his description by means of lantern slides and curves.

Mr. Hoit pointed out the adaptability of the tungsten lamp to series street lighting, comparing the same to gas and electric arc and carbon lamps.

The following members took part in the discussion: Messrs. C. A. Culverwell, H. W. Price, K. L. Aitken, F. A. Gabey, A. J. Soper, W. R. Sweeny, E. Richards, A. L. Mudge, P. H. Mitchell Eugene Creed, J. E. Bullard, H. C. Gooding, E. B. Merrill. Sixty-eight members and visitors attended the meeting.

Urbana Section

Secretary Ralph W. Pope was the guest of the Urbana Section at a meeting held on November 16, 1909, in the University of Illinois.

Mr. Pope was introduced by Dr. Charles P. Knipp, and spoke of some of the problems he had encountered during his years of administration of Institute affairs, and of the growth of the Institute during that period. In conclusion he mentioned some of the engineering problems now being worked out in New York City, in connection with the new tunnels of the Pennsylvania Railroad Company, and the Hudson Terminal Building.

Washington University Branch

The Washington University Branch held its regular meeting on November 16, 1909. Mr. George W. Lamke was elected vice-chairman. Messrs. Barnes and Duncan then presented a paper on "Tests on the East St. Louis and Suburban Railway", based upon their gradua-

tion theses. Their work represented a large number of personal observations, and the compiling of the data proved very tedious. Mr. G. W. Pieksen gave a description of "Standardized Interurban Equipment", as used on the Illinois Traction system.

The third meeting for the year was held on December 6, 1909, in Cupples Hall No. 2. It was devoted to a general discussion on "Engineering Education", based on articles which have appeared from time to time in the Institute PROCEEDINGS and other engineering publications. The need of good English in the engineering courses, and the amount of practical education actually necessary were commented on. The Institute papers reviewed were: "Concentric Method of Engineering Education", by V. Karapetoff, reviewed by William Rose; "Value of Classics in Engineering Education", by Charles P. Steinmetz, reviewed by H. F. Thomson; "Relation of the College Graduate to the Manufacturer", by Messrs. Rushmore and Behrend.

WASHINGTON SECTION

The Washington Section held a meeting on November 16, 1909, in conjunction with the Washington Society of Engineers, at George Washington University. The program consisted of an address by Mr. Louis B. Marks, consulting engineer, of New York, on "Factory Lighting", which was illustrated by lantern slides. Mr. Marks spoke at length on the unsatisfactory, unhygienic, and inefficient methods of localized lighting in general use, and the benefits to be derived from a more even distribution of diffused illumination. There was a total attendance of 42 members of both societies.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

A meeting of the Worcester Polytechnic Institute Branch was held on Friday evening, November 19, 1909, in the electrical engineering hall. Eighty members and friends were present to hear Mr. N. J. Neall's paper on "High-Voltage Transmission and Lightning Protection." Proposing a problem involving a power station and three substations, Mr. Neall carried through a series of calculations by means of a method evolved by Mr. Percy H. Thomas and explained the advantages of this method over others. After brief consideration of the results thus obtained, and the power required to supply line losses, an explanation was given of Thomas' method of reducing these losses by increased capacity effect produced by an increase of conductor surface. The next points considered in the line calculation were the pole line, spans, height of poles, size and material of wire, sag of the conductors, types of insulators, and methods of lightning protection and the performance of lightning protective apparatus. To illustrate some of the existing constructions a number of lantern slides were shown, also charts and tell-tale papers showing operating conditions.

On December 3, 1909, the Branch was addressed by Mr. J. W. Corning, electrical engineer of the Boston Elevated Railway Company, on "Some Electrical Features of the Boston Elevated Railway System." After a few introductory remarks Mr. Corning outlined the history of the company's development from the time of the consolidation of several horse car lines in 1888, to the installation of electric motive power and power stations. A map of Boston was used to show the location of the centers of power distribution, and an explanation given of the feeder system and the means by which points between stations may be operated from either in case of the disability of one. To show the character of the load on railway lines Mr. Corning explained a curve of total system load during 24 hours, supplementing his explanation with some deductions as to the movement of the

city's population as indicated by the curve. Another curve of average temperature and maximum load from five to six o'clock p.m. each day for one year served to illustrate the effect of temperature on load. In considering the distribution system, Mr. Corning told of the gradual introduction of conduit feeders, and the increase in their size, illustrating some of the troubles encountered with this type of line. He also explained the operation of the system of multiple unit control and the electric switch. One hundred members were present to hear the lecture.

Personals

MR. F. G. WIECHMANN has removed his offices from No. 1 Madison Avenue to Room 908, 24 State Street, New York.

MR. THOMAS D. LOCKWOOD, after several months abroad, returned home on the Steamship Oceanic on December 15, 1909.

MR. E. W. T. GRAY has succeeded Mr. George Preston Sheldon as president of the Phenix Insurance Company, Brooklyn, N. Y.

MR. T. R. MILLAR has accepted a position on the engineering staff of the Ontario Power Company, Niagara Falls, Ont.

MR. J. G. ROBERTS has been appointed patent attorney and expert for the Western Electric Company, New York.

MR. W. J. B. DREW is now associated with The Canadian Light and Power Company, 403 Eastern Townships Bank Building, Montreal, Canada.

MR. DON M. RICE is now connected with the engineering department of the American Telephone and Telegraph Company, at 15 Dey Street, New York.

MR. C. E. BOMAN has severed his connection with the New York Telephone Company to enter the equipment engineering department of the Western Electric Company at Hawthorne, Ill.

MR. M. C. CARPENDER has been appointed mechanical engineer of the Hudson Valley Railway Company, an electric railway, with headquarters at Glens Falls, N. Y.

MR. S. R. A. CLEMENT, formerly of the switchboard department of the General Electric Company, Schenectady is now with the Hydro-Electric Power Commission of Ontario, Toronto, Ont.

MR. G. W. SAATHOFF has left the employ of the Westinghouse Electric and Manufacturing Company, at St. Louis, to accept a position with the Spring River Power Company, of Joplin, Mo.

MR. THOMAS W. WILKINSON has accepted an appointment as manager of an urban exchange for the Kansas City Long Distance Telephone Company. His post office address is Hickman Mills, Mo.

MR. ARCH K. WOOD, electrical superintendent for the New River and Pocahontas Consolidated Coal Company at Gentry, W. Va., was appointed on December 1, 1909, assistant superintendent of that company.

MR. S. L. NICHOLSON has been appointed general sales manager of the Westinghouse Electric and Manufacturing Company, and has direct charge of the sales policies of the entire company.

MR. G. A. HARRIS, engineer of the Japanese engineering and contracting firm of Takata & Company, has removed his office from 60 Wall Street to the Hudson Terminal Building, 50 Church Street, New York.

MR. M. E. WEEKS, who for more than two years was employed as electrical draftsman at the Norfolk Navy Yard, was transferred on November 1, 1909, to a similar position with the Bureau of Equipment.

MR. JOSEPH B. CRANE, former manager of the Broadalbin Electric Light & Power Company, has resigned his position to take up work as commercial engineer with the Great Northern Power Company, Duluth, Minn.

MR. CHARLES ROBBINS, for many years connected with the Westinghouse Electric and Manufacturing Company, in the industrial and power sales department, was recently appointed manager of that department.

MR. A. R. STRAUB has given up his position as foreman with the Western Electric Company to become superintendent of the Dale Electric Company, New York. Mr. Straub was with the Western Electric Company for 15 years.

MR. JOHN P. MOORE, formerly superintendent of distribution of the Des Moines Electric Company, Des Moines, Iowa, is now instructor in electric railway engineering at Pennsylvania State College, State College, Pa.

MR. C. A. BERRY having resigned as superintendent of switchboard installation, Western Electric Company, has accepted a position in the engineering department of the American Telephone and Telegraph Company, New York.

MR. F. D. NIMS has resigned his position as chief operating engineer of the Mexican Light and Power Company, Ltd., Mexico City, to become chief constructing engineer of the Western Canada Power Company at Vancouver, B. C.

MR. PHILIP SHERIDAN, after an extended pleasure trip in Mexico and the United States, has resumed his duties with the Guanajuato Amalgamated Gold Mines Company, La Luz, Guanajuato, Mexico, where he expects to remain permanently.

MR. J. R. CLARK, after three and a half years' service in various departments of the Western Electric Company at their Hawthorne plant, has entered the employ of the Barber-Colman Company, Rockford, Ill., in the superintendent's office.

PROFESSOR B. F. GROAT of the University of Minnesota, is spending a year's leave of absence in practical hydraulic engineering. He is at present making a hydraulic survey in northern New York under the instructions of Mr. John R. Freeman.

MR. HENRY FLOY, having recently returned from making an investigation and report on some railway properties in Alabama, is now actively engaged in making a valuation of the various properties controlled by the Third Avenue Railroad Company in New York.

MR. DONALD MCNICOL, who until recently was secretary of the Utah Society of Engineers at Salt Lake City has been transferred by the Postal Telegraph Cable Company to its engineering department in New York City, where he will be a member of the engineering staff.

MR. THOMAS E. DANIELS, who has been connected with the High Creek Light and Power Company since its inception, resigned his position as engineer on November 1, 1909. He is at present with the Capitol Electric Company, of Salt Lake City, as erecting engineer and salesman.

MR. J. B. KILMORE, formerly engineer for the commerical department of the Scranton Electric Company, one of the properties of the American Gas & Electric Company, has been transferred to Conshohocken, Pa., as general

manager of their gas and electric properties at that place.

Mr. C. Stowe Reno, who for the last 15 years has been chief engineer of the Triumph Electric Company, has resigned to accept the position of treasurer and manager of the Expanded Metal Engineering Company, whose headquarters are in the Brunswick Building, 225 Fifth Avenue, New York.

Mr. O. S. Newton, who for two and a half years was chief engineer with the Mansfield Railway, Light & Power Company, Mansfield, Ohio, has left that company to accept the position of electrical engineer with The Buckeye Mining & Smelting Company, a Mansfield concern with properties at Big Pine, Cal.

Mr. W. S. Finlay, Jr., formerly assistant engineer to Mr. H. G. Stott, of the Interborough Rapid Transit Company, and later with J. G. White & Company, has become mechanical engineer of the New England Engineering Company, engineers and contractors, with offices at 113 Church Street, New Haven, Conn.

Mr. W. S. Bourlier has left the construction department of the General Electric Company to accept a position as electrical engineer with the Washington, Baltimore and Annapolis Electric Railway Company, with headquarters at Odenton, Md. At present he has charge of the rolling stock and the power department of the company.

Mr. G. A. Harvey, who for the last six years has been the electrical engineer of the International Railway Company, of Buffalo, N. Y., recently resigned that position to take up work in the West. He is residing temporarily at Colorado Springs, Colorado, where he expects to remain until he forms a new connection.

Dr. Charles P. Steinmetz will address a meeting to be held under the auspices of the Washington University Association, St. Louis, Mo., on January 6, 1910, on the subject of "Industrial Use of Luminescence." The members of the St. Louis Section of the A. I. E. E. and other local engineering societies have been invited to attend the meeting. On January 7 Dr. Steinmetz will address a meeting at the University of Missouri, Columbia, Mo.

Annual Meeting of the American Society of Mechanical Engineers

The thirtieth annual meeting of the A. S. M. E. was held in the Engineers' Building, 33 West 39th Street, New York, December 7–10, 1909. The professional papers mentioned in Section I of the December Proceedings were presented and discussed. Mr. George Westinghouse was elected president, to serve until the annual meeting in December, 1910.

Obituary

Dr. Charles B. Dudley, chief chemist for the Pennsylvania Railroad Company, died at his home in Altoona, Pa., on Tuesday evening, December 21, 1909, of typhoid pneumonia, after an illness of three days. Dr. Dudley was born at Oxford, Chenango County, N. Y., on July 14, 1842. He was graduated from Yale University in 1871, and from the Sheffield Scientific School in 1874. Subsequently he became assistant to the professor of physics at the University of Pennsylcania. In November 1875, he became associated with the Pennsylvania Railroad Company as chemist and scientific expert, retaining this position to the time of his death. In his capacity as chemist for the Pennsylvania Railroad Company he performed work of much importance in testing railway materials, establishing a standard which has been adopted by nearly all of the railroads in this country.

Dr. Dudley was president of the American Chemical Society, the Iron and Steel Institute, the International Association for Testing Materials, and the American Society for Testing Materials. His presidential address before the latter society, on "Engineering Responsibility", delivered on June 29, 1909, was reprinted in the December issue of the Institute PROCEEDINGS. He became an Associate of the Institute on October 1, 1889, and was transferred to the grade of Member on November 12, 1889.

MR. EDWARD ANDREW BRISCOE, engineer of the Colorado department, Telluride Power Company, Telluride, Colorado, died suddenly on Tuesday, November 9, 1909. Mr. Briscoe was born at Tipton, Missouri, on October 21, 1877. On graduating from the Tipton High School he entered the collegiate department of the University of Missouri, subsequently becoming an instructor. After three years of teaching he took the engineering course at the university, and was graduated in 1903 with the degree of B.Sc. Leaving for the West shortly afterward, he entered the employ of the Telluride Power Company, at Provo, Utah, continuing with this company up to the time of his death. He became an Associate of the Institute on January 27, 1905. He is survived by his widow, and parents, and several brothers and sisters.

Notice has just been received of the death on July 30, 1909, of MR. WILLIAM W. LYON, JR. Mr. Lyon was born on December 16, 1882. He took the course in electrical engineering at Columbia University, and later entered the employ of the New York Central & Hudson River Railroad Company. At the time of his death he was associated with the Public Service Commission, New York City. He became an Associate of the Institute on January 27, 1905.

Library Accessions*

The following accessions have been made to the Library of the Institute since the last acknowledgment.

Acetylene Gas Machines, which have been examined under the Rules and Requirements of the National Board of Fire Underwriters. October, 1909. Chicago, 1909. (Exchange.)

Albany Vocational School. (New York State Education Department—Division of Trades Schools.) Albany 1909. (Gift.)

American Railway Association. Statistical Bulletin no. 59-A. Chicago, 1909. (Gift.)

Applications of Electricity to Propulsion of Naval Vessels. By W. L. R. Emmet. (Society of Naval Architects and Marine Engineers, Nov. 1909.) (Gift.)

Automatic Sprinklers which have been examined under the Standard of the National Board of Fire Underwriters by the National Fire Protection Association, November, 1909. n. p. n. d. (Exchange.)

Board of Supervising Engineers Chicago Traction. Annual Report 1st. Chicago, 1908. (Gift of B. J. Arnold.)

Boston Transit Commission. Annual Report 15th, Boston, 1909. (Gift.)

Building and Equipping the Non-Magnetic Auxiliary Yacht Carnegie with Producer Gas Propelling Equipment. By W. Downey. (Society of Naval Architects and Marine Engineers, Nov. 1909.) (Gift.)

"National Electrical Code" Installation Rules (except marine work) of the National Board of Fire

*The Library Accession list published every month in the PROCEEDINGS includes additions to the library of the Institute only. Similar accession lists of the libraries of the American Institute of Mining Engineers and the American Society of Mechanical Engineers are published by those societies. Copies of these lists may be obtained without charge upon application to the secretary of the Institute.

Underwriters for Electric Wiring and Apparatus. 1909. n. p. 1909. (Gift.)

National Society for the Promotion of Industrial Education. Bulletin no. 9. Proceedings of 2d Annual Meeting, Atlanta, Georgia. New York, 1909. (Gift.)

National Society for the Promotion of Industrial Education, New York State Branch. Constitution and List of Members. 1908. New York, 1908. (Gift.)

New York (City) Board of Water Supply. Annual Report. 2d New York City, 1907. (Gift of Dr. Samuel Sheldon.)

New York State Department of Labor. Annual Report of the Bureau of Labor Statistics, 26th. Part 1. Industrial Training. Albany, 1909. (Exchange.)

New York State Public Service Commission. First District. The Matter of Certifying Types of Electric Current Energy Meters. (Case no. 1100.) New York, 1909. (Exchange.)

— The Matter of a Standard Form of Reports on Testing of Electric Meters. (Case no. 1154.) New York, 1909. (Exchange.)

——The Matter of the Application of the Bronx Gas and Electric Company for Approval of Issue of Bonds of Par Value of $1,500,000, Secured by First Mortgage, whereof $740,000 to be issued forthwith to Retire $500,000 Outstanding Bonds and For Other Purposes. (Case no. 1160.) New York, 1909. (Exchange.)

—In the Matter of the Double-tracking of the Flushing-Jamaica and the College Point Lines of the New York & Queens County Railway Company. (Case no. 1066.) New York, 1909. (Exchange.)

Pour l' Aviation. Par D'Estournelles de Constant, and others ed. 3. Paris. (Gift.)

Preliminary Abstract of Reports for the year ended Dec. 31, 1908, of the Consolidated Telegraph and Electrical Subway Company, Empire City Subway Company. (Form R 39) New York Edison Company, Long Acre Electric Light and Power Company. (Form R 38.) New York, 1908. (Exchange.)

Registrierungen des spezifischen Leitvermögens der Atmospharischen Luft. von H. Schering. n. p. 1908. (Gift of Physikalisch-Technische Reichsanstalt.)

Rugby Engineering Society. Proceedings, vol. V. Rugby. 1907–08. (Exchange.)

Rules and Requirements of the National Board of Fire Underwriters for the Construction and Installation of Centrifugal Fire Pumps as Recommended by the National Fire Protection Association. 1909. (Exchange.)

Rules and Requirements of the National Board of Fire Underwriters for the Manufacture of 1¼ in., 1½ in. and 2½ in. Unlined Linen Fire Hose for Use Inside Buildings, as Recommended by the National Fire Protection Association. 1909. (Exchange.)

Rules and Requirements of the National Board of Fire Underwriters for the Manufacture of Private Department Fire Hose for Mill Yard Use as Recommended by the National Fire Protection Association. 1909. (Exchange.)

Sea Strength. (Office of Naval Intelligence, Navy Dept.) Nov. 1, 1909. (Gift.)

Society of Arts of the Massachusetts Institute of Technology Lists of Members, Dec. 1909. Boston, 1909. (Gift.)

Specifications of the National Board of Fire Underwriters for the Construction and Care of Hose for Fire Department Use, as Recommended by the National Fire Protection Association. 1909. (Exchange.)

Spon's Workshops Receipt for Manufacturers and Scientific Amateurs. Vols. 1–2. London, 1909. (Gift

of Spon and Chamberlain.) Price, $1.50 net each.

CONTENTS:—Volume I.—Acetylene Lighting; Acidimetry; Aerating Agents; Albumen; Alcohol; Alcoholometry; Alkalimetry; Alkaloids; Alloys; Aluminium paper; Amalgam; Amber; Anemometers, and the Determining of Air Currents; Aqua Fortis; Aqua Regia; Aquarium, Repairing Leaks in; Baking Powders; Ball Valves (noisy); Bamboo Work; Barometers and Weather Glasses; Basket Making; Bell Founding and Bell Metal; Belting; Bitters; Blackboard Wash or Liquid Slating; Blackings and Leather Polishes; Bleaching; Boiler Corrosion; Boiler Incrustation and Boiler Compositions; Boiler and Pipe Covering Compositions; Bookbinding and Book Repairing; Briquettes or Block Fuel; Burnishing; Cameo Cutting; Camera Lucida; Camera Obscura; Candles and Candle Making; Catgut; Celluloid and Ivory Substitutes; Cements and Lutes; Charcoal; Chemical Chimney Cleaner; Chimneys, their Action and Causes of Failure; China Riveting; Chisel Steel and its Treatment; Cleansing; Clock and Watch Mending; Coal Economizing Powder; Concrete; Confectionery; Cooking Apparatus; Cooking Range; Copying; Crayons or Pastels; Dampness in Buildings; Dendrometer; Dental Porcelain; Dew Ponds; Dipping and Coloring Brass; Disinfectants; Distilling; Door Hanging; Drain Pipe Jointing and Testing; Drawing; Drying and Desicating.

Volume II.—Dyes and Dying; Earth Closets; Ebonite and Vulcanite; Electric Batteries, their Construction and management; Electric Bells and Alarms; Electric Motor for Use in a Small Workshop; Electric Wiring; Electro-Plating and Electro-Deposition; Embalming; Emulsifying and Emulsions; Enamelling for Artistic and Commercial Purposes; Engraving; Etching; Evaporating; Explosives and Blasting Compounds; Files; Sharpening and Re-cutting; Filtration and Percolation; Fire-Grates; their Working Principle and Fixing; Fire-Proofing; Fire-Prevention; Fire-Extinguishing Compounds and Appliances; Fireworks; Floorcloth and Oilcloth; Fountains, Illuminated and Prismatic; Fountains, Self-Acting, Freezing Mixtures; Fuel Economy; Galvanometers; Gas Fitting, Gas Heating Appliances; Gas Mantle Manufacturers; Gauging and Ullage of Casks; Gilding; Glass; Glass Paper, Sand and Emery Paper and Cloth; Glass Stoppers; Loosening; Glazing Bricks; Glazing Windows; Lead Glazing; Glue, Gelatine, Size and Izinglass; Glycerine, Grinding Metals; Gun "Proof" Marks; Gutta-Percha; Hot Water Apparatus; Indirect Heating of Water; Hydraulic Rams; Fixing and Working; Incubators; India Rubber; Induction Coils; Inks; Ivory; Japan and Japanning.

Steam Turbine. By J. A. Moyer. New York, J. Wiley & Sons, 1908. (Gift of publishers.)

CONTENTS:—Chapter I.—Introduction. Chapter II.—Elementary theory of Heat. Chapter III.—Nozzle Design. Chapter IV.—Steam Turbine Types and Balde Design. Chapter V.—Mechanical Losses in Turbines. Chapter VI.—Method for Correcting Steam Turbine Tests. Chapter VII.—Commercial Types of Turbines Chapter VIII.—Governing Steam Turbines. Chapter IX. Low-Pressure (exhaust) Turbines. Chapter X.—Marine Turbines. Chapter XI.—Tests of Turbines. Chapter XII.—Steam Turbine Economics. Chapter XIII.—Stresses in Rings, Drums and Disks. Chapter XIV.—Gas Turbines. Chapter XV.—Electric Generators for Turbines.

Strength of Water-tight Bulkheads. By W. Hovgaard. (Society of Naval Architects and Marine Engineers, Nov. 1909.) (Gift.)

Uber die Abhangigkeit des Emissionsvermögens der Metalle von der Temperatur. Von E. Hagen und H. Rubens. n. p. n. d. (Gift of Physikalisch-Technische Reichsanstalt.)

Uber die Messung der Korpertemperatur mit arztlichen Minuten-Maximumthermometern. von H. F. Wiebe. n. p., 1909. (Gift of Physikalisch-Technische Reichsanstalt.)

Specifications and Patents of the U. S. Patent Office, Certified copies. 1871–1887, 274 vols. (Gift of the Western Electric Co.)

Specifications and drawings of patents relating to electricity. July 1887–Dec. 1907. 210 vols. (Gift of Western Electric Co.)

Underwriters' Laboratories. General Information in Reference to Underwriters' Laboratories. October, 1909. (Exchange.)

Utilization of Fuel in Locomotive Practice. (Bulletin no. 402, U. S. Geological Survey.) By W. F. M. Goss. Washington, 1909. (Gift of W. J. Jenks.)

War Ship Tonnage of the Principal Naval Powers. (Office Naval Intelligence, Navy Dept.) Nov. 1, 1909. (Gift.)

Westinghouse Electric and Manufacturing Company *vs.* Bullock Electric Manufacturing Company. Opinion of the Circuit Court. Injunction Motion. Nov. 22, 1909. New York. n. d. (Gift.)

Gift of Library of Columbia University

Berg, W. N., Comparative Study of the Digestibility of Different Proteins in Pepsin-Acid Solutions. New York, 1909.

——Darling, C. A., Sex in Dioecious Plants. New York, 1909.

——Eddy, W. H. On the Synthesis of Some Protein Salts. Easton, 1909.

——Gortner, R. A. On Some New Quinazoline Derivatives. Easton, 1909.

——Kress, Otto. Does Thorium Exist as Thorium Silicate in Monazite? New York, 1909.

——Lothrop, A. P. Effect of Bone Ash in the Diet on the Gastro-Intestinal Conditions of Dogs. New York, 1909.

——Rosenbloom, Jacob. Contribution to the Study of the Nature and Origin of the Bence Jones Protein. Easton, 1909.

——Steel, M. Study of the Influence of Magnesium Sulfate on Metabolism. New York, 1908.

Trade Catalogues

Allgemeine Elektricitats-Gesellschaft, Berlin. Experimental lecture on electrical measuring apparatus by Alexander Königswerther. 16 pp.

——A. E. G. arc lamp pulley attachment, making lamp safe and reliable. 4 pp.

——Bulletin No. 53 on cables manufactured at the A. E. G. cable works. 8 pp.

——Oil switches for direct and alternating current. 4 pp.

——Prevention of street railway accidents by means of self acting, automatic sand box attachment. 2 pp.

American Diesel Engine Co., New York, N. Y. American Diesel engine, operating with safe, crude, or fuel oils. 66 pp.

American Radiator Co., Chicago, Ill. Ideal Heating—a booklet on the advantages of radiator heating. 48 pp.

——"Results Successful"—a book of simple rules for running ideal boilers. 20 pp.

——"The Homes Successful"—a book on the comforts and advantages of radiators for heating purposes. 40 pp.

Central Electric Co., Chicago, Ill. Economical meter tests made with P-M meter connection blocks. 15 pp.

Chicago Pneumatic Tool Co., Chicago Ill. The Franklin high speed air compressor, type G H. 4 pp.

Conveying Machinery Co., New York, City. Bulletin No. 208 on high speed fans. 12 pp.

Crocker-Wheeler Co., Ampere, N. J. Numerical Index to bulletins, Nov. 1909. 1 page.

——Bulletin No. 116 on motor generator sets for all purposes. 12 pp.

——Bulletin No. 117 on motor drive in the laundry. 16 pp.

——Bulletin No. 118 on form L direct current motors, 1/20 to 7½ h.p. generators. .6 to 3.5 kw. 16 pp.

Electric Controller & Mfg. Co., Cleveland, O. June, 1909, "Common Sense" a magazine devoted to the interests of electric appliances and products of this firm. 32 pp.

Electrocraft Publishing Co., Detroit, Mich. Bulletin No. 3, December, 1909, containing advance information on new electrical material. 4 pp.

——Articles: "Coöperation between contractors and the central station; "An effective pipe bending device;" "The Contractor's wider field." 4 pp.

General Electric Co., Schenectady, N. Y. Bulletin No. 4702 on fire boats of New York, Chicago, San Francisco, etc. 16 pp.

——Improved type H transformer. 2 pp.

Holpohane Co., Newark, Ohio. "Holophane Illumination," November, 1909, devoted to illumination by the Holophane system. 16 pp.

Leeds & Northrup Co., Phila., Pa. Herrick inspection test set for rapidly and accurately determining the condition of the equipment of electric cars. 4 pp.

——Telescope galvanometer, and insulation testing galvanometer. 4 pp.

——Kelvin bridge for the measurement of low resistances. 4 pp.

——Electrical thermometers and pyrometers. 5 pp.

——Resistance thermometers, and precision instruments for all temperatures. 32 pp.

National X-ray Reflector Co., Chicago, Ill. Reprint from the "Fine Arts Journal" — "A new light for art galleries, libraries, and museums" — "Development of indirect illumination." 8 pp.

Ohio Brass Co., Mansfield, Ohio. O. B. Bulletin, October, 1909, a magazine devoted to the interests of construction and operation of electric railways and electric mining. 24 pp.

Robinson Radial Car Truck Co., Brooklyn, N. Y. Robinson radial car track systems for electric railway service. 24 pp.

Sanderson & Porter, San Francisco, Cal. Reprint from "Journal of Electricity, Power and Gas, article: The Stanislaus Power Development of the Sierra and San Francisco Power Co. 20 pp.

Scully Steel & Iron Co., Chicago, Ill. November 1909, stock list of iron and steel supplies. 96 pp.

Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Additions to perpetual catalogue No. 3001 as catalogue sections on transformer fuse boxes, meters, plug switches, Tungsten lamp street lighting systems, and new discount sheet. 46 pp.

——Portable standard integrating wattmeters. 12 pp.

——Circular No. 1094 on Westinghouse turbo-generator sets. 38 pp.

——Circular No. 1103 on the Westinghouse series-multiple arc lamps; direct current. 12 pp.

——Circular No. 1177 on Materials for switchboard panels. 12 pp.

——Circular No. 1181 on Portable direct current ammeters and voltmeters. 8 pp.

UNITED ENGINEERING SOCIETY
GIFT OF J. MCALLISTER STEVENSON, JR. AND LOUIS T. STEVENSON

——Baker, T. Treatise on the Mathematical Theory of the Steam Engine. London, 1864.

——Bennett, F. M. Steam Navy of the United States. Pittsburgh, 1896.

——Bourne, John. Handbook of the Steam Engine. New York, 1865.

——Haupt, Herman. General Theory of Bridge Construction. New York, 1866.

——Nason, H. B. Manual of Qualitative Blowpipe Analysis. Philadelphia, 1881.

——Nystrom, J. W. Technological Education and the Construction of Ships and Screw Propellers, for Naval and Marine Engineers. Edition 2. Philadelphia, 1866.

——Perry, M. C. United States Japan Exhibition. Volumes 1–3. Washington, 1856.

——Turnbull, John. Short Treatise on the Compound Engine. Glasgow, 1873.

——U. S. Coast Survey. Coast Pilot of Alaska. (Part 1) 1869. Washington, 1869.

——U. S. Navy Department. Report of the Secretary 1867, 1873, 1876, 1880, 1885, vol. 1, 1887. Washington, 1867, 1873, 1876, 1880, 1885, 1887.

——U. S. Navy Department, Office of Naval Intelligence. Annual, July 1892. Washington, 1892.

——Ward, J. H. Elementary Instruction in Naval Ordnance and Gunnery. New York, 1861.

——International Exposition, St. Louis, 1904. Official Catalogue. Exhibition of the German Empire. Berlin. (Gift of Prof. F. W. Hutton.)

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LIST OF SECTIONS.

(Revised to December 1, 1909.)

Name and when Organized	Chairman.	Secretary.
Atlanta...........Jan. 19, '04	H. P. Wood.	M. E. Bonyun, G. E. Co., Atlanta, Ga.
Baltimore.........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, 107 East Lombard St., Baltimore, Md.
Boston............Feb. 13, '03	D. C. Jackson.	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago..................1893	W. L. Abbott.	J. G. Wray, 203 Washington St., Chicago, Ill.
Cleveland.........Sept. 27, '07	H. L. Wallau.	F. M. Hibben, 807 The Cuyahoga Bldg., Cleveland, O.
Fort Wayne.......Aug. 14, '08	E. A. Wagner.	J. V. Hunter, 506 W. Jefferson St., Ft. Wayne, Ind.
Ithaca............Oct. 15, '02	E. L. Nichols.	B. C. Dennison, Cornell University Ithaca, N. Y.
Los Angeles.......May 19, '08	J. A. Lighthipe.	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Madison..........Jan. 8, '09	M. H. Collbohm.	H B. Sanford, Univ. of Wisconsin, Madison, Wis.
Mexico...........Dec. 13, '07	E. Leonarz.	W. A. Ferguson, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota.........Apr. 7, '02	J. C. Vincent.	J. H. Schumacher, 2716 University Ave., Minneapolis, Minn.
Norfolk...........Mar. 13, '08		R R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia.......Feb. 18, '03	Geo. A. Hoadley.	H. F. Sanville, 1708 Sansom St., Philadelphia, Pa.
Pittsburg..........Oct. 13, '02	C. B. Auel.	E. B. Tuttle, C. D. & P. Tel. Co., Pittsburgh, Pa
Pittsfield..........Mar. 25, '04	H. W. Tobey.	L. F. Blume, G. E. Co., Pittsfield, Mass.
Portland, Ore......May 18, '09	O. B. Coldwell.	L. B. Cramer, 720 Corbett Building, Portland, Ore.
San Francisco.....Dec. 23, '04	George R. Murphy.	S. J. Lisberger, 445 Sutter St., San Francisco, Cal.
Schenectady.......Jan. 26, '03	M. O. Troy.	R. H. Carlton, Gen. Elec. Co., Schenectady, N. Y.
Seattle............Jan. 19, '04	J. H. Harisberger.	George Homes Moore, City Engineer's Office, Seattle, Wash.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	George W. Lamke, Washington University, St. Louis, Mo.
Toledo............June 3, '07	M. W. Hansen.	Geo. E. Kirk, 1649 The Nicholas, Toledo, O.
Toronto...........Sept. 30, '03	H. W. Price.	W. H. Eisenbeis, 1207 Traders' Bank Bldg., Toronto, Can
Urbana...........Nov. 25, '02	Charles T. Knipp.	J. M. Bryant, 610 West Oregon St., Urbana, Ill.
Washington, D. C. Apr. 9, '03	Philander Betts.	M. G. Lloyd, Bureau of Standards, Washington, D. C.

Total, 24.

LIST OF BRANCHES.

(Revised to December 1, 1909.)

Name and when Organized.	Chairman.	Secretary.
Agricultural and Mechanical College of Texas............Nov. 12, '09		
Arkansas, Univ. of..Mar. 25, '04	W. B. Stelzner.	F. S. White, 523 Willow St., Fayetteville, Ark.
Armour Institute...Feb. 26, '04	Edward Sherwin.	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Case School, Cleveland.............Jan. 8, '09	C. N. Weems.	S. G. Hibben, 2171 Cornell St., Cleveland, O.
Cincinnati, Univ. of..Apr. 10, '08	C. R. Wylie.	Ralph B. Kersay, 315 Jackson St., Carthage, Ohio.
Colorado, Univ. of...Dec. 16, '04	E. A. Robertson.	A. P. Sunnergren, 1209 Penn., Boulder, Colo.
Iowa State College...Apr. 15, '03	F. A. Fish.	Adolph Shane, Iowa State College, Ames, Ia.
Iowa, Univ. of.......May 18, '09	H. E. Scheark.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col. Jan. 10, '08	R. E. Talley.	B. F. Eyer, 513 Fremont St., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	V. S. Foster.	R. L. Ponsler, Univ. of Kansas, Lawrence, Kans.
Lehigh University....Oct. 15, '02	W. W. Broadbent.	Howard M. Fry, Lehigh University, Bethlehem, Pa.
Lewis Institute.......Nov. 8, '07	Frank Burch.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Michigan, Univ. of...Mar. 25, '04	E. B. McKinney.	Gerald J. Wagner, 454 S. First St., Ann Arbor, Mich.
Missouri, Univ. of....Jan. 10, '03	H. B. Shaw.	A. E. Flowers, Univ. of Missouri, Columbia, Mo.
Montana State Col...May 21, '07	C. C. Kennedy.	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of...Apr. 10, '08	Geo. H. Morse.	V. L. Hollister, Station A, Lincoln, Nebraska.
New Hampshire Col..Feb. 19, '09	A. M. Buck.	T. A. Thorp, New Hampshire College, Durham, N. H.
Ohio State Univ......Dec. 20, '02	G. A. Arnold.	E. C. Williamson, 181 West 8th Ave., Columbus, O.
Oregon State Agr. Col. Mar. 24, '08	E. R. Shepard.	W. Weniger, Ore. State Agricul. College, Corvallis, Ore.
Penn. State College...Dec. 20, '02		
Purdue Univ.........Jan. 26, '03	J. W. Esterline.	H. T. Plumb, Purdue University, Lafayette, Ind.
Rensselaer Polytechnic Institute.......Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y.
Stanford Univ.......Dec. 13, '07	C. L. Bradley.	C. P. Taylor, Stanford University, California
Syracuse Univ.......Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of......Feb. 14, '08	B. E. Kenyon.	J. A. Correll, University of Texas, Austin, Tex.
Washington Univ....Feb. 26, '04	H. F. Thomson.	George W. Pieksen, Washington University, St. Louis, Mo.
Worcester Poly. Inst..Mar. 25, '04	Ray H. Taber.	C. E. Putnam, Worcester Poly. Inst., Worcester, Mass.

Total, 27.

NOTE

The following paper is to be read at the regular meeting of the American Institute of Electrical Engineers in **New York City, January 14, 1910.** This meeting is to be held under the auspices of the Railway Committee of the Institute. All members of the Institute are invited to be present and participate in the discussion of the paper.

Written contributions will be read at the meeting for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of the contributors.

The object of issuing the paper in advance of the meeting is to increase the interest and authority of the discussion by affording those desiring to participate a longer time for the study of the paper and the preparation of their views.

Those desiring to contribute to the discussion of this paper, either orally or by letter, should notify **William McClellan, Chairman Railway Committee, 90 West Street, New York** not later than Jan 12, 1910. Written contributions should be in his hands by that date.

EDISON MEDAL

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE A WARDLAW, Editor

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All other countries $12.00 per year.
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½ page	30.00	25.00	22.00

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Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXIX **February, 1910** No. 2

Meeting A. I. E. E. Feb. 11, 1910

The two hundred and forty-third meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York, ... February 11, 1910
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ing to discuss this paper, either orally or by letter, should notify William Maver, Jr., Chairman Telegraphy and Telephony Committee, 136 Liberty Street, New York, not later than February 9, 1910.

Institute Meeting at Charlotte, N. C., March 30-April 1, 1910

At the meeting of the Institute Board of Directors held on December 16, 1909. a resolution was passed authorizing the Meetings and Papers Committee to arrange for a meeting of the Institute at some suitable point in the South Atlantic states during the month of March, 1910, to comprise such number of sessions as may be deemed desirable. One of the reasons actuating the Board in determining upon this meeting is the importance of the electrical work now in progress in the southern states, and it was believed that a meeting of this kind would not only afford an unusual opportunity for the presentation and discussion of papers, but would also promote closer relations with our southern members.

The Meetings and Papers Committee has decided that the meeting shall be held at Charlotte, N. C. on March 30, 31 and April 1, 1910. The program has not yet been completed, but arrangements have already been made for the presentation of the following papers: "Economics of Hydroelectric Plants", by W. S. Lee; "Electric Drive in Textile Mills", by A. Milmow; "Gas Engines in City Railway and Light Service", by E. D. Latta, Jr., "A Method of Protecting Insulators from Lightning and Power Arc Effects with Results of its Installation on the Lines of the Niagara & Lockport Power Co." by L. C. Nicholson. In addition to a number of attractive social features, the Southern Power Company has kindly offered to place at the disposal of the members in attendance a special train for a tour of inspection of its Great Falls and Rocky Creek stations at Great Falls, S. C., and a 100,000-volt sub-station. This trip will be arranged so that the party can return to Charlotte before evening. The official headquarters will be at the Selwyn Hotel, which is on the European plan. Other hotels in Charlotte are: Stonewall Hotel, European plan; Buford Hotel, European and American plan;

Central Hotel, American plan. A local Committee of Arrangements has been appointed by President Stillwell, and is constituted as follows: W. S. Lee, chairman, C. I. Burkholder, E. P. Coles, S. W. Cramer, John H. Finney, J. W. Fraser, E. D. Latta, Jr., F. M. Laxton, R. R. Laxton, F. D. Sampson, A. M. Schoen, J. E. Sirrine, C. E. Waddell, and Dr. W. Gill Wylie. It is hoped that a representative attendance, especially of the southern membership will be present. It should be understood that this meeting is not to take the place of the Institute's annual convention. Additional details will be published in the March PROCEEDINGS.

Annual Dinner, February 24, 1910

The Annual Dinner of the Institute will be given at the Hotel Astor, New York City, on the evening of Thursday, February 24, 1910, at 7:00 o'clock. The guest of honor on that occasion will be Professor Elihu Thomson, to whom the first Edison Medal has just been awarded. It is intended to give this distinguished scientist a welcome befitting his great services to the Institute and the scientific world at large.

President Stillwell has appointed the following Dinner Committee: Robert T. Lozier, Chairman, George H. Guy, Secretary, Theodore Beran, Maurice Coster, Minor M. Davis, George A. Hamilton, F. L. Hutchinson, T. C. Martin, A. S. McAllister, Wm. McClellan, H. W. Pope, F. A. Scheffler, Samuel Sheldon, Albert Spies, S. D. Sprong, and Arthur Williams.

The following are the names of the chairmen of the sub-committees: Place and Date: Albert Spies; Attendance: Theodore Beran; Speakers and Guests: Samuel Sheldon; Music and Menus: George H. Guy; Decorations: Arthur Williams; Seating: William McClellan.

The committee is already busily engaged in making its plans and arrangements. The speakers will include several men of prominence in the engineering profession. Special attention is being paid to decorations, music, and the souvenir menu. The price of the dinner, for which an excellent menu has been provided, is $6.00, including one wine, cigars and cigarettes. Applications for reservation of seats should be addressed to Ralph W. Pope, Secretary of the Institute. As usual on these occasions, ladies will participate, and a total attendance of at least 500 or 600 is expected.

The Edison Medal Award

The gold Edison Medal was awarded by the Institute, through its Edison Medal Committee, for the first time, on December 16, 1909, to Elihu Thomson for "Meritorious Achievement" in electrical science, engineering and arts, as exemplified in his contributions thereto during the past 30 years.

A parchment Certificate of Award, which, under the by-laws of the Medal Committee, constitutes the official notice of award, will be issued to Dr. Thomson on February 24, 1910, at the Annual Dinner of the Institute.

The medal will be presented at the next Annual Meeting of the Institute in May.

CHARLES L. CLARKE,
Chairman, Edison Medal Committee.

Student Diploma of Merit Award

A diploma of Merit and cash sum of one hundred and fifty dollars were awarded by the Institute, through its Edison Medal Committee, on May 18, 1909, to Trygve Jensen, a graduate student of the University of Illinois, for his record of research, entitled: "Operation of a 100,000-Volt Transformer", submitted in competition therefor.

The original "Deed of Gift Creating the Edison Medal", dated February 11, 1904, provided for the award of the gold Edison Medal "to such qualified student as shall have submitted to the

Institute * * * the best thesis on record of research on theoretical or applied electricity or magnetism."

As theses or records of research in competition for the Edison Medal were not forthcoming within a reasonable time, the Institute became convinced that the medal foundation was upon an impracticable basis, for reasons stated by the chairman of the Medal Committee, and published in the PROCEEDINGS for May, 1908.

Thereupon the foundation was changed, after efforts to that end were begun in the spring of 1907, through the execution of a new deed, dated March 26, 1908, entitled: "Amended and Substitute Deed of Gift Creating the Edison Medal", by the terms of which the medal is now awarded "to someone resident of the United States and its Dependencies, or of the Dominion of Canada, for 'Meritorious Achievement in Electrical Science or Electrical Engineering or the Electrical Arts."

Before the execution of the new deed was fully completed, however, several students entered theses or records of research in competition for the medal under the old deed of February 11, 1904, then still in force. Nevertheless, at the desire of the Institute, all of them at once generously withdrew from competition for the medal and resubmitted their work in a new competition for the Diploma of Merit and cash award of one hundred and fifty dollars, which have been awarded to Mr. Jensen.

CHARLES L. CLARKE,
Chairman, Edison Medal Committee.

Institute Meeting at Boston, Mass., February 16, 1910

A meeting of the Institute in coöperation with the American Society of Mechanical Engineers, authorized by the Board of Directors at its December meeting, is to be held in Boston, Mass., on Wednesday, February 16, 1910, in the auditorium of The Boston City Club, 9 Beacon Street, Boston. Arrangements have been made for the presentation of the following papers: "The Applicability of Electrical Power to Industrial Establishments", by Dugald C. Jackson; "Central Stations, versus Isolated Plants for Textile Mills", by Charles T. Main. "The Supply of Electrical Power for Industrial Establishments from Central Stations", by R. S. Hale; "Illumination for Industrial Plants", by G. H. Stickney; "The Requirements for an Induction Motor from the User's point of View", by Walter S. Nye.

Meeting A.I.E.E., March 11, 1910

The regular March meeting of the Institute will be held in the Engineers' Building, 33 West 39th Street, New York City, on Friday, March 11, 1910 in coöperation with the American Institute of Mining Engineers. The following tentative program has been arranged for this meeting: "Electric Mine Hoists", by D. B. Rushmore; "Electric Mine Hoists with Illgner Motor Generator Set", by R. R. Seeber; "Comparison of Electric and Compressed Air Drives for Mine Hoists", by K. A. Pauly; "Electric Mine Hoists", by W. Sykes. Additional information will be published in the March PROCEEDINGS.

Institute Meeting at San Francisco, April 21, 1910

A meeting of the Institute under the auspices of the High-Tension Transmission Committee will be held in San Francisco, Cal., on Thursday, April 21, 1910. Among the papers which will be presented at this meeting are the following: "The Economics of a General Power System", by John A. Britton; "The Developed High-Tension Network of a General Power System", by Paul M. Downing; "Hydroelectric Developments and Irrigation", by John Coffee Hays. Further details regarding this meeting will be published in a subsequent issue of the PROCEEDINGS.

Directors Meeting, Jan. 14, 1910

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at 33 West 39th Street, New York City, on Friday, January 14, 1910. The directors present were: President Lewis B. Stillwell, New York; Past-President Henry G. Stott, New York; Vice-Presidents C. C. Chesney, Pittsfield, Mass., Bancroft Gherardi, New York, Paul M. Lincoln, Pittsburgh, Pa.; Managers P. H. Thomas, New York, W. S. Murray, New Haven, Conn., D. B. Rushmore, Schenectady, N. Y., H. E. Clifford, Cambridge, Mass., H. H. Norris, Ithaca, N. Y., S. D. Sprong, New York, A. W. Berresford, Milwaukee, Wis.; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary Ralph W. Pope, New York.

Eighty-eight candidates for admission to membership in the Institute as Associates were elected, as per list printed elsewhere in this PROCEEDINGS.

Sixty-seven applicants for enrolment as Students were ordered enrolled.

Four Associates were transferred to the grade of Member, as follows:

WILLIAM ROBINSON, Electrical and Mechanical Engineer, Brooklyn, N. Y.

EZRA FREDERICK SCATTERGOOD, Consulting Electrical Engineer and Chief Electrical Engineer, City of Los Angeles, Cal.

PAUL WINSOR, Chief Engineer, motive power, Boston Elevated Railway System, Boston, Mass.

ADOLPHUS MANSFIELD DUDLEY, Designing Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Meeting of the Institute January 14, 1910

The two hundred and forty-second meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 W. 39th Street, New York City, on Friday evening, January 14, 1910. President Lewis B. Stillwell presided and called the meeting to order at 8:20 p.m. Assistant Secretary Hutchinson announced that at the meeting of the Institute Board of Directors held during the afternoon 88 Associates were elected, and four Associates were transferred to the grade of Member. President Stillwell then announced the subject for the evening, entitled " On the Space Economy of the Single-Phase Series Motor ", by Professor W. S. Franklin and Mr. S. S. Seyfert, both of Lehigh University, Bethlehem, Pa. Professor Franklin then presented the paper, which was discussed by Messrs. S. M. Kintner, E. H. Anderson, E. F. W. Alexanderson, S. S. Seyfert, and W. S. Franklin.

Institute Meetings Under the Auspices of Sections

At its meeting held on January 14, 1910, the Institute Board of Directors adopted the following resolutions:

Whereas, the national conventions of the Institute do not afford adequate opportunity for the presentation and discussion of all the papers of value which are submitted to the Meetings and Papers Committee; and

Whereas, it has been customary for many years to supplement the work of the annual convention in respect of papers and discussions by Institute meetings at the Institute headquarters in New York, on the second Friday of each month from October to May inclusive; and

Whereas, it is believed that additional papers of general interest would be prepared and incorporated in the records of the Institute were it possible for a larger proportion of the membership to attend one or more Institute meetings during the year;

Resolved, that the Secretary be instructed to inform the officers of the local Sections that the Board of Directors is prepared to authorize additional meetings of the Institute to be held under the auspices of one or more local Sections upon application to the Board of Directors through the Meetings and Papers Committee; provided, however, that the program proposed and the paper or papers to be presented are first approved by the Meetings and Papers Committee.

Advance copies of such papers as may be offered and accepted shall be dealt with by the Institute in the usual manner. All papers must be forwarded to the secretary not less than two months prior to the date of presentation.

Resolved, that nothing in the foregoing resolutions shall be construed to limit or qualify the authority of the local Sections in holding such other meetings as they may deem advisable.

Publication of Communications

The following resolutions regarding the publication of informal communications in the Institute PROCEEDINGS were adopted by the Board of Directors at its meeting on January 14, 1910.

Whereas, members of the Institute are at times in a position to contribute to the PROCEEDINGS material deemed by them of insufficient importance to justify presentation in formal papers, but nevertheless valuable as records of experience or deduction tending to advance the theory and practice of electrical engineering: and

Whereas, it is deemed desirable that such material should be made available to the membership of the Institute.

Resolved, that the secretary be instructed to call the attention of the membership to the fact that the Institute is prepared to receive and publish communications other than formal papers, upon the following conditions:

(1) The communications shall be submitted in writing to the Meetings and Papers Committee.

(2) If approved by the Meetings and Papers Committee the communication shall be presented for discussion, by title or otherwise, at an Institute meeting and shall be duly published in the PROCEEDINGS.

(3) Following publication in the PROCEEDINGS opportunity will be afforded for written discussion which may be forwarded to the secretary by any member desiring to participate.

In passing upon the question of acceptance or rejection of such communications the Meetings and Papers Committee shall accept no material for the PROCEEDINGS which would lower the Standard established in the case of formal papers.

All discussions of such communications and all questions regarding the publication of such discussions in the PROCEEDINGS and TRANSACTIONS of the Institute shall be passed upon by the Editing Committee.

Nominations

For the purpose of giving information to the membership in connection with future nominations for officers of the Institute, after the distribution of the nomination forms, in February, the following by-law was adopted by the Board of Directors November 13, 1908:

SEC. 18. For the guidance of members in the selection of nominees for the annual election there shall be published in the January and February PROCEEDINGS, each year, a summary of the nomination votes of the preceding year containing the names of all persons having received at least three per cent of the entire number of nomination votes cast, and also the names of all directors not included in this list and of ex-Vice-Presidents and Managers who have held office at any time during the preceding five years.

In compliance with this by-law the following list has been compiled:

GENERAL PROPOSAL LIST, APRIL, 1909

NOTE: Names printed in italics indicate that these officers were elected and their terms began on August 1, 1909.

FOR PRESIDENT

Lewis B. Stillwell	722
Ralph D. Mershon	39
J. G. White	38

FOR VICE-PRESIDENTS

J. J. Carty	471
Paul M. Lincoln	265
Paul Spencer	203
A. M. Schoen	178
E. J. Berg	171
A. M. Hunt	111
Ralph D. Mershon	66
J. P. Jackson	60
W. S. Murray	40

FOR MANAGERS

A. W. Berresford	587
W. S. Murray	426
H. H. Norris	243
S. D. Sprong	143
H. B. Smith	139
Henry Floy	105
N. W. Storer	45
W. S. Rugg	41
J. F. Stevens	40

FOR TREASURER

George A. Hamilton	853

FOR SECRETARY

Ralph W. Pope	858
F. L. Hutchinson	59

PRESENT DIRECTORS NOT INCLUDED IN ABOVE GROUPS

Morgan Brooks
Harold W. Buck
Willard G. Carlton
Cummings C. Chesney
H. E. Clifford
Louis A. Ferguson
Bancroft Gherardi
Benjamin G. Lamme
David B. Rushmore
Charles W. Stone
Henry G. Stott
Percy H. Thomas
Calvert Townley

EX-VICE-PRESIDENTS AND MANAGERS WHO HAVE HELD OFFICE DURING THE LAST FIVE YEARS NOT INCLUDED IN ABOVE GROUPS

A. H. Armstrong
W. S. Barstow
Frank G. Baum
Charles L. Clarke
Gano Dunn
Charles L. Edgar
W. C. L. Eglin
W. E. Goldsborough
H. H. Humphrey
C. O. Mailloux
Samuel Reber
Calvin W. Rice
George F. Sever
Charles A. Terry
Schuyler S. Wheeler
Townsend Wolcott

Associates Elected Jan. 14, 1910

ABBOTT, ARTHUR HOWARD, Assistant Engineer, Transformer Engineering Dept., General Electric Co., Pittsfield, Mass.

ACKLAND, ARTHUR EDWARD, Manager and Engineer, The National Electrical & Engineering Co., Wellington, N. Z.

ADLER, GEORGE MAX, Electrical Engineer, New England Fish Co., Ketchikan, Alaska.

BARNETT, EDWIN LESTER, Electrician, Union Lumber Co., Fort Bragg, Cal.

BEERS, HAROLD SMITH, General Electric Co.; res., 158 Nott Terrace, Schenectady, N. Y.

BERST, CHARLES BRUBAKER, Apprentice, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

BULLIVANT, FRANCIS JAMES, Electrical Engineer, Wagner Electric Mfg. Co.; res., 937 Beach Ave., St. Louis, Mo.

BUTTERFIELD, JOSEPH THOMPSON, Assistant Instructor in Electrical Engineering, Purdue University, Lafayette, Ind.

CABOT, WALTER KINSMAN, Master Mechanic's Office, Western Electric Company, 463 West Street, New York City.

CHASE, GEORGE HOWELL, Instructor, Central Office School, Bell Telephone Co. of Pa., 1635 Arch Street, Philadelphia, Pa.

CHATFIELD, LIONEL CLYDE, Tester, General Electric Co.; res., 604 Rugby Road, Schenectady, N. Y.

CLARK, RHODOLPHUS PHILIP, Assistant, Experimental & Research Laboratory, General Electric Co., Schenectady, N. Y.

CLARKSON, ERNEST PALMER, Manager, Cobalt Electric Equipment Co., Cobalt, Ontario.

CREGO, STANLEY MILLARD, Standardizing Laboratory, Bldg. No. 4, General Electric Co., Schenectady, N. Y.

DAWSON, HORACE LATHROP, Engineer, The Cutler-Hammer Mfg. Co., 1138 Monadnock Bldg., Chicago, Ill.

DUFF, DONALD STEER, Resident Electrical Engineer, F. & C. Osler Ltd., 188 Mount Road, Madras, India.

DU MOULIN, WALTER LOUIS, Engineer, Cananea Consolidated Copper Co., Cananea, Sonora, Mexico.

DUSTIN, FRED GERRISH, Chief Electrical Inspector, Dept. of Buildings, City Hall, Minneapolis, Minn.

EARDLEY, MEHRING VERE, Switchboard Inspector, General Electric Co., Schenectady, N. Y.

EBY, EUGENE DE WITT, Designing Engineer, Transformer Dept., General Electric Co., Pittsfield, Mass.

EVANS, JOHN, Chief Engineer, The Denver City Tramway Co.; res., 400 8th Ave., Denver, Colo.

FARNSWORTH, LOUIS DUZZETT, Electrical Engineer, Westinghouse, Church Kerr & Co., 10 Bridge Street, New York City.

FLETCHER, GEORGE HERBERT, Chief Tester, Dick, Kerr & Co., Ltd., Preston, England.

FOSTER, EDWARD S., Instructor in Electrical Engineering, Lehigh University; res., 501 Cherokee St., So. Bethlehem, Pa.

GARCELON, GEORGE HOLLAND, Designing Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

GATI, BELA, Post and Telegraph Engineer-in-Chief, VI Hajosu 33–35, Budapest, Hungary.

Gorham, John Sharon, Electric Vehicle Specialist, C. P. Kimball & Co., 315 Michigan Ave., Chicago, Ill.

Hamilton, Horace Lester, Technical Writer, N. W. Ayer & Son, 300 Chestnut St., Philadelphia, Pa.

Hanley, Newton Franklin, Electrical Engineer, General Electric Co.; res., 35 Dalton Ave., Pittsfield, Mass.

Harbolt, Percy Francis, Assistant Superintendent, Electric Repair Shop, Indiana Steel Co., Gary, Indiana.

Harding, Vernon Alexander, Supervising Engineer, Burns & McDonnell, 823 Scarritt Bldg., Kansas City, Mo.

Hellmuth, William Frederick, Chief Electrician, Black Creek Coal Company, Harleigh, Pa.

Horle, Ferdinand George, Engineer, The Cutler-Hammer Mfg. Co., 1138 Monadnock Bldg., Chicago, Ill.

Howard, O. Zell, Mechanical Engineer, United States Naval Experiment Station; res., 50 Franklin St., Annapolis, Md.

Hurd, Elmer, Forman of Construction, Pasco Reclamation Co., Pasco, Wash.

Hurley, Wallace P., Assistant in Electrical Engineering,Carnegie Technical Schools, Pittsburg, Pa.

Jacobi, Will Orlando, Designing Engineer on Power Plant, Pullman Car Company, Chicago, Ill.

Johnson, Conrad John, Inspector, Central District and Printing Telegraph Co., Wheeling, West Virginia.

Kawara, Masaki, Electrical Engineer, General Electric Co.; res., 618 Chapel St., Schenectady, N. Y.

Keith, David Forbes, Assi tant Station Supt., Grace Station, Telluride Power Co., Provo, Utah.

Kerr, William Alexander, Chief Enneer, The Asbestos & Asbestic Co., Asbestos, Quebec.

Koster, Edward John, Engineer Assistant, New York Telephone Co., 15 Dey Street, New York City.

Lauridsen, Laurids, Engineer, W. S. Barstow & Co., 419 Failing Building Portland, Oregon.

Lawrence, Henry Edmunds, Professor of Physics, University of Rochester, Rochester, N. Y.

Le Fever, Orland Lester, Foreman of Subway Construction, W. S. Barstow & Co., 419 Failing Bldg., Portland, Ore.

Linter, John, Electrical Engineer, General Administration of Russian Posts and Telegraphs, St. Petersburg, Russia.

Lloyd, Eugene MacDonald, Meter Tester, Westinghouse Electric & Mfg. Co., Newark, N. J.

Mann, Ned Chester, Student, University of Missouri; res., 505 Conley Ave., Columbia, Mo.

Marshall, William, Student, Cornell University; res., 209 Williams St., Ithaca, N. Y.

McCullough, William Wallace, Jr., Telluride Power Co., Telluride, Colo.

Millar, Ernest George Blythe, Student, University of Missouri, Columbia, Mis ouri.

Montes, Carlos Soler, Superintendent Red Telefonica de Camaguey, Camaguey, Cuba.

Murphy, Raymond G., Laboratory Assistant, Standardizing Laboratory, General Electric Company, Schenectady, N. Y.

Newman, Walter Allen, Electrical Inspector, The Board of Fire Underwriters, Portland, Ore.

Page, Wilson Kingman, Test Man, General Electric Co.; res., 618 Chapel St., Schenectady, N. Y.

Palmer, Everett Arthur, Cadet Engineer, Public Service Railway Co.; res., 321 Belleville Ave., Newark, N.J.

Powell, Herbert Charles, Inspector, Smith, Kerry and Chace, Toronto; res., 268 West Ave., N., Hamilton, Ont.

Pratt, Fred Cameron, Student, University of Illinois; res., 1001 W. Illinois St., Urbana, Ill.

Price, Bernard, Chief Engineer, Victoria Falls & Transvaal Power Co., 507–511 Consolidated Bldg., Johannesburg, So. Africa.

READ, GUY CARLETON, Electrical Engineer, Cobalt Light, Power & Water Co., Ltd., Cobalt, Ontario.

ROGERS, JOSEPH WILLIAMS, Electrical Supervisor, West Jersey & Seashore Railroad Co., 22 Federal Street, Camden, N. J.

ROSSMAN, ALLEN M., Lighting Engineering Department, General Electric Company, Schenectady, N. Y.

SANDERSON, EUGENE WILLIAM, Western Electric Co., 156 W. 15th Street, New York City.

SCHAEFER, JOSEPH HARVEY, Chicago Telephone Co., 203 Washington St.; res., 1435 No. Washtenaw Ave., Chicago, Ill.

SHEFFER, JOHN WESLEY, Electrical Engineer, American Car and Foundry Co., Berwick, Pa.

SIBLEY, HINSON SMITH, Assistant Engineer, Birmingham Ry. Light and Power Co., Birmingham, Ala.

SIGWALT, ELMER JACOB, Inspector, Board of Supervising Engineers, 181 La Salle St., Chicago, Ill.

SITHENS, EDWARD JONES, Assistant Engineer, Bell Tel. Co. of Pa., 11th & Filbert Streets, Philadelphia, Pa.

SOWLES, LEWIS W., Utah Light & Railway Co.; res., 130 3rd East Street, Salt Lake City, Utah.

STANTON, ROBERT M., Electrical Engineer, Cohocton, N. Y.

STREAMER, A. CAMP, Westinghouse Electric & Manufacturing Co., Pittsburg; res., 511 Franklin Ave., Wilkinsburg, Pa.

SURFACE, CHARLES RANDALL, Student, University of Missouri; res., 201 College Ave., Columbia, Mo.

SWEETMAN, ARTHUR HENRY, Designing Electrical Engineer, Cosmopolitan Electrical Co., 115 Dearborn St., Chicago, Ill.

TAYLOR, WILLIAM GORTON, Foreman of Testing, General Electric Co.; res., 229 Seward Place, Schenectady, N. Y.

THUT, PAUL, Chief Superintendent Bernische Kraftwerke, A. G., 7 Thunstrasse, Bern, Switzerland.

URBAN, FREDERICK, 3031 Park Hill Ave., Milwaukee, Wis.

UYEDA, YOSHITAKE, Student, University of Pennsylvania; res., 17 Bodine Dorms., Philadelphia, Pa.

WARD, EVANS, Construction Engineer, Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N. Y.

WARD, WARREN LELAND, Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

WARNER, OSCAR CZAR, 2nd Lieutenant, Coast Artillery Corps, United States Army, Fort Worden, Wash.

WARNER, FRANK LEE, Draftsman, General Electric Co.; res., 116 Victory Avenue, Schenectady, N.Y.

WARNIMONT, ROBERT KIMBALL, Sub-Station Operator, Chicago and Oak Park Elevated Railroad, Chicago, Ill.

WATSON, JAMES THOMAS, Electrical Engineer, Tennessee Copper Co., Copperhill, Tenn.

WATT, HAROLD WOODRUFF, Cadet Engineer, Westchester Lighting Co., Tarrytown, N. Y.

WEIRICH, PAUL JOSEPH, General Supt., The Monroe Telephone Co., Monroe, Wisconsin.

WILLS, GEORGE M., The Nevada-California Power Co., Goldfield, Nevada.

WOOTEN, ONNIE B., Instructor, Dept. of Physics, Texas Agricultural and Mechanical College, College Station, Texas.

WYNNE, VALENTINE CHARLES, Electrical Engineer, with State Architect; res., 858 Madison Ave., Albany, N. Y.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before February 25, 1910.

9110 Burcher, R. H., Brooklyn, N. Y.
9111 Hicks, A. T., Trenton, Ont.
9112 MacNaughton, D., Milwaukee, Wis

9113 Senour, D. Z., Chicago, Ill.
9114 Buchert, E., Newark, N. J.
9115 Chapman, D. A., Boston, Mass.
9116 Gunby, F. M., Boston, Mass.
9117 Keyes, E. F., Pullman, Wash.
9118 Sanford, R. L., Burlington, Vt.
9119 Ward, R. V., Pasadena, Cal.
9120 Allen, H. V., Schenectady, N. Y.
9121 Samukawa, T., Tokyo, Japan.
9122 Petty, D. M., South Bethlehem, Pa.
9123 Bradley, J. C. G., Baltimore, Md.
9124 Culbertson, R. K., Pittsburg, Pa.
9125 Edgell, F. V., South Boston, Mass.
9126 Hirsch, J. G., Madison, Wis.
9127 Naul, J. M., Pittsfield, Mass.
9128 Willson, E. L., Wilkes-Barre, Pa.
9129 Curry, C. C., Minneapolis, Minn.
9130 Deffenbaugh, H.C., Rochester, N.Y.
9131 Dishington, J. R., Racine, Wis.
9132 Henley, Lloyd, Oakland, Cal.
9133 Love, F. B., Findlay, Ohio.
9134 Martell, H. C., Balboa, C. Z.
9135 Oswald, F., Findlay, Ohio.
9136 Smeltzer, L. W., Chicago, Ill.
9137 Townsend, F. P., Elyria, Ohio.
9138 Tracy, E. G., Schenectady, N. Y.
9139 Curtis, W. F., New York City.
9140 Espenchied, Lloyd, New York City.
9141 Kilburn, E. E., Waterbury, Conn.
9142 Knipmeyer, C.C., Terre Haute, Ind.
9143 Richardson, G. E., Boston, Mass.
9144 Bull, E. W., Regina, Can.
9145 Graff, S. D., Boston, Mass.
9146 Kerr, W. C., Philadelphia, Pa.
9147 Soule, W. H., Montreal, Canada.
9148 Starrett, J. P., Boston, Mass.
9149 Calvert, J. E., Grass Valley, Cal.
9150 Corwin, M. J., Seattle, Wash.
9151 Farnsworth, P., Summit, N. J.
9152 Fisk, I. W., Urbana, Ill.
9153 Lawton, A., Oakland, Cal.
9154 Ryder, J. L., Los Angeles, Cal.
9155 Richardson, E. B., Boston, Mass.
9156 Brown, B. O., Washington, D. C.
9157 Cantin, A. J., Chicago, Ill.
9158 Carlton, H., Pittsfield, Mass.
9159 Claytor, W. G., Roanoke, Va.
9160 Date, W. E., New York City.
9161 Egy, W. L., Chicago, Ill.
9162 Forsythe, R. L., Enterprise, Ore.
9163 French, E. R., Elizabeth, N. J.
9164 Hallborg, H. E., Brant Rock, Mass
9165 Hudgins, J. D., Annapolis, Md.
9166 Nichols, F. A., Buffalo, N. Y.
9167 Affolter, P. H., Laramie, Wyoming
9168 Allan, W. G., Lancashire, England.
9169 Boe, H. F., Pittsburg, Pa.
9170 Brimson, G. J., Pittsfield, Mass.
9171 Dyer, E. K., Los Angeles, Cal.
9172 Johnston, W. D., Butler, Pa.
9173 Keys, H. M., Atlanta, Ga.
9174 Reinhard, L. F., Milwaukee, Wis.
9175 Sprunt, H. W., London, England.
9176 Tate, A. O., Toronto, Canada.
9177 von Wellen, L. J., Albany, Ga.
9178 Bullis, S. M., Vicksburg, Miss.
9179 Burke, J.H., Long Island City, N.Y.
9180 Eirich, C., Los Angeles, Cal.
9181 Gasche, F. G., So. Chicago, Ill.
9182 Graham, E. A., Hamilton, Ont.
9183 Hyer, R. G., Mt. Vernon, N. Y.
9184 Kenyon, J. S., Elizabethport, N. J.
9185 Pollock, R. T., Ashland, Mass.
9186 Searle, E., Worcester, Mass.
9187 Swales, G. O., Pullman, Wash.
9188 Griffith, M. J., Havelock, Neb.
9189 Lattin, R. B., Hartford, Conn.
9190 Baker, R. L., Joplin, Missouri.
9191 Bivens, J. P., New York City.
9192 Chedsey, W. R., Moscow, Idaho.
9193 Forbush, W. A., Bridgewater, Mass
9194 Grossman, H. M., Cleveland, O.
9195 Hollenbeck, B. A., Chicago, Ill.
9196 Johnson, P. H., Madison, Wis.
9197 King, Thomas, Ulladulla, N. S. W.
9198 Perry, F. G., Boston, Mass.
9199 Blauvelt, W. G., New York City.
9200 Latham, E. W., Brooklyn, N. Y.
9201 Moffit, L. R., Atlanta, Ga.
9202 Moulton, W. R., Chicago, Ill.
9203 Ostrander, J. K., Chicago, Ill.
9204 Slocum, B. W., Portland, Ore.
9205 Mohr, S. M., St. Petersburg, Rus.
9206 Hackel, J. M., St. Petersburg, Rus.
9207 Pace, J. D., Cobalt, Ont.
9208 Irwin, B., Charlotte, N. C.
9209 Harrill, A. V., Charlotte, N. C.
9210 Armstrong, E. S., Charlotte, N. C.
9211 Brown, B. J., Charlotte, N. C.
9212 Hanks, W. W., Charlotte, N. C.
9213 Andrews, E. W., Charlotte, N. C.
9214 Connelly, R. P., Charlotte, N. C.
9215 Owens, S. H., Charlotte, N. C.
9216 Kimbreel, M. R., Charlotte, N. C.
9217 Jones, J. M., Charlotte, N. C.
9218 Bradfield, J. M., Charlotte, N. C.

9219 Stephens, J., Charlotte, N. C.
9220 Wooten, E. Y., Charlotte, N. C.
9221 Latta, A. W., Charlotte, N. C.
9222 Gatchel, F. D., Charlotte, N. C.
9223 Davis, T. R., Charlotte, N. C.
9224 Harrison, J., Charlotte, N. C.
9225 Caldwell, L. D., Kings Mountain, N. C.
9226 Rutledge, G. H., Concord, N. C.
Total, 117.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at a meeting held on January 14, 1910. Any objection to these transfers should be filed at once with the Secretary.

FRANK M. TAIT, Engineer and General Manager, Dayton Lighting Company, Dayton, Ohio.

W. F. STUART-MENTETH, Electrical Engineer, Public Works Department, Bombay Government, Bombay, India.

LOUIS C. MARBURG, Electrical and Mechanical Engineer, Allis-Chalmers Company, Milwaukee, Wis.

ROBERT B. WILLIAMSON, Electrical Engineer, Allis-Chalmers Company, Milwaukee, Wis.

THOMAS COMMERFORD MARTIN, Executive Secretary, National Electric Light Association, 29 West 39th Street, New York City.

CHARLES H. MERZ, Consulting Engineer, 28 Victoria Street, Westminster, London, England.

Fuel Tests with House-Heating Boilers

"Fuel Tests with House-Heating Boilers," by J. M. Snodgrass, is issued by the engineering Experiment Station of the University of Illinois as Bulletin No. 31. It reports 130 tests of anthracite, Pocahontas coal, coke and Illinois coal made in connection with two types of house-heating boilers. Copies may be obtained gratis upon application to W. F. M. Goss, Director of the Engineering Experiment Station, University of Illinois, Urbana, Illinois.

Current Transformers*

BY P. C. MORGANTHALER

It is the intention to consider only the application of the current transformer to and its effect upon electrical measuring instruments, particularly the instruments whose operation depends not only upon definite magnetic fields, but also the phase-angle between them. These instruments include wattmeters, watt-hour meters, power-factor meters, etc., but only the two former will be considered here. The measurement of alternating volts, amperes, and watts, has been and is now, a most vital one, at least so far as ordinary commercial measurements are concerned.

For ordinary commercial use it is not usually advisable, to connect measuring instruments directly with the circuit. This is done to protect the operator from accidental injury, and even where the voltage conditions are such that no injury could result, it is necessary to introduce some device to increase the range of the instrument beyond the restricted limits of the current windings.

In most cases it is convenient to employ current and potential transformers, which means, of course, that the accuracy of these devices must be known or that the instrument be checked on the primary side of the transformers. It is not convenient to choose the latter, as this requires the use, in many cases, of large capacity standards as well as the attending danger of handling high-voltage circuits. While such standards are employed, their use is generally confined to the laboratory, as they cannot be handled conveniently as portable instruments. There remains, then, only one course: The instrument must be checked as a secondary instrument, and its operation, when the transformer is introduced, must be known.

In the measurement of alternating potential involving the use of the potential transformer, the prime requi-

* A paper presented at the Fort Wayne Section, November 22, 1909.

site of the latter is that the ratio remains constant. In fact, this is the only restriction placed upon the potential transformer when used in connection with a voltmeter. Since the range of voltage measurements is generally confined to a small variation for a given transformer, it is obvious that the ratio will be practically constant. When, however, the potential transformer is used for supplying the voltage or potential circuit of a wattmeter or watt-hour meter, the phase-angle between the primary and secondary volts, as well as the ratio, should be constant. These instruments, fortunately, are similar in this respect to the voltmeter—the variation in voltage generally being confined to a small amount—so that the phase-angle can be considered constant. The potential transformer, then, will be eliminated from the discussion on the basis that it is generally operating at a given constant load, so that the phase-angle and ratio may be considered constant.

In the measurement of alternating amperes the chief consideration is that the ratio remains constant. In fact, this is the only restriction placed on the current transformer for current measurement, as the phase-angle between the primary and secondary current does not enter into the problem at all.

In the measurement of power in an alternating-current circuit when the use of a current transformer is necessary, both the phase-angle and the ratio must remain constant, since a variation from normal in either will affect the results. It is obvious that variations in the phase-angle will affect the readings of the wattmeter or watt-hour meter, as the torque of either of these devices is a function of the cosine of the phase displacement between the current and potential fields, as well as a function of the field strength of both.

It would be comparatively an easy matter to design a current transformer for instrument work were it not for the restrictions placed upon it when used with wattmeters or watt-hour meters. Considering the instrument alone, a wattmeter or watt-hour meter to measure true power or true energy must be so designed and constructed that the field of the current circuit and the field of the potential circuit (at unity power-factor) are in phase or exact quadrature, depending, of course on the principles involved. In some instruments, such as wattmeters operating on the Siemens electrodynamometer principle, there exists a slight angle between the two fields, appearing as an angle of lag in the potential circuit. However, in a well-designed wattmeter this angle is usually too small to be considered at all, and in this discussion will be entirely ignored. Wattmeters and watt-hour meters operating on the induction principle, requiring fields in quadrature, are usually provided with a lag-coil so there will be no existing error when correctly adjusted.

It is obvious that the conditions existing in the wattmeter or watt-hour meter, when operating alone, will be altered in some manner upon the introduction of the current transformer. The current circulating in the secondary will not be in exact opposition to the current flowing in the primary, except under certain limited conditions. In order fully to understand this, it should be remembered that the current flowing in the primary is made up of two components—that necessary to excite the core and that appearing in the secondary circuit by induction. These components, except under certain conditions, cannot be combined in a straight line; therefore, it can be readily seen that the current appearing in the secondary will not be in phase (rather opposition) with the primary current, thereby causing a difference between the indication of the wattmeter or watt-hour meter when used with a current transformer and when used without a transformer. Wattmeters and watt-hour meters are affected, of course, to the same extent as ammeters by changes in the ratio.

Current-transformers, as usually constructed, when carrying an instrument-load give a leading current in the secondary, affecting the wattmeter or watt-hour meter the same as if the current in the potential circuit were lagging. In order fully to understand the relation existing between the various components of the current in the current transformer, attention is directed to Fig. 1. In this Fig. *i e* represents the exciting current plotted as ampere-turns; *I s*, the secondary current plotted as ampere-turns; *I p*, the primary current plotted as ampere-turns reversed to simplify the diagram, the flux being plotted vertical and the induced electromotive force horizontal, the diagram being drawn, counter clockwise

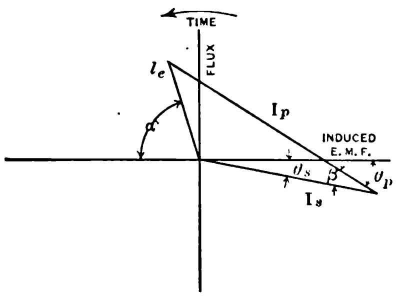

Fig. 1

as indicated by the arrow. The exciting current is plotted as the ampere-turns necessary to produce the voltage $I_s Z_s$, where I_s is the secondary current and Z_s the impedance of the secondary load. This load, it should be remembered, consists of two parts, that external to the transformer, and that due to the impedance of the windings. The angle-of-lag of the exciting current is represented by a the angle-of-lag of the primary current by θ_p; the angle-of-lag of the secondary current by θ_s; and the phase-angle between the primary and secondary currents by B; the secondary current leading the primary current as shown in this particular diagram. In actual practice, it should be remembered that the magnitude of the exciting current is very small as compared with the primary or secondary current, this diagram being very much exaggerated in order to obtain a clear conception of its operation.

This Fig. shows that the phase-angle and ratio between the primary and secondary currents are functions of the secondary impedance ohms, power-factor of the secondary load, power-factor of the exciting current, and the ampere-turns for which the transformer is designed. It would be well, at this time, to call attention to the fact that the wattmeter or watt-hour meter readings are more seriously affected by a change in the phase-angle when operating on inductive loads, the lower the power-factor the greater will be the error for a given condition of the phase-angle.

Now that it has been determined just what factors affect the phase-angle and ratio, it would be interesting to know just how this is brought about. It is obvious that, since the secondary impedance voltage is a function of the exciting current, any change in the impedance ohms of the secondary load will cause a co responding change in the exciting current, which, in turn, must be furnished by the primary current. Assuming a given constant load in the primary, the ratio between the primary and secondary current must, of necessity, be affected by changes in the secondary impedance ohms. Even though the secondary impedance be made up entirely of resistance, any change in the exciting current will alter the phase-angle between the primary and secondary current (except under one condition, to be described later) since the latter are, for a given primary load, functions of the exciting current.

It is also obvious from the diagram that any change in the power-factor of the secondary-connected load will likewise affect the ratio and phase-angle. Assuming the secondary impedance ohms as constant, in order that the exciting current will be constant, any change in the reactance of

the secondary load will alter the angle θ_s, which, in turn will alter the phase-angle B. Under the same assumption, and a given constant primary current, the secondary current I_s must also vary with the angle θ_s thereby affecting the ratio.

The power-factor of the exciting current will also affect the ratio and phase-angle, for the reason that, with a given primary current and secondary-connected load, the angle θ_p will vary with the power-factor of the exciting current, thereby affecting the ratio and phase-angle.

It has already been explained how the exciting current affects the ratio and phase-angle. The ampere-turns for which the transformer is designed will affect these functions in a similar manner.

With the foregoing information, it is quite obvious that the secondary current may lead or lag behind the primary current; that is, the phase-angle B may be positive or negative, depending on the power-factor of the secondary load. If the power-factor of the secondary load is higher than the power-factor of the exciting current, the secondary current will be leading; if lower, the secondary current will be lagging. If the power factors are equal, the phase-angle will be zero, or the primary and secondary currents will be in exact opposition.

An examination of the diagram will also show that, with non-inductive load on the secondary, the ratio will be but little effected while the phase-angle will be effected to a considerable degree by variations in the exciting current. On the other hand, if the secondary power-factor is low, say approximately that of the exciting current, changes in the exciting current will have considerable effect upon the ratio, but scarcely any effect upon the phase-angle.

Summing up wha has already been said, it can be briefly stated that, since the current appearing in the secondary is the algebraic difference between the current circulating in the primary and the exciting current, any conditions that will alter the magnitude of the exciting current or the angle between the primary and exciting currents will affect the secondary current, and, therefore, the ratio and phase-angle.

It is also obvious that the ratio cannot hold throughout the entire range of the transformer, since, with a given connected secondary load, the exciting current necessary to produce the voltage to force the secondary current through its impedance will not bear the same proportion to the primary current. That is, the relation between the exciting current and primary current will not bear the same proportion at various loads.

With the foregoing information at hand, it is obvious that while the current transformer is a remarkably accurate device, its accuracy depends very largely upon actual service conditions. For example, the same results cannot be obtained when operating with several devices connected to the secondary of the transformer as when operating with a single induction watt-hour meter. For this reason, knowing the phase-angle and ratio under various conditions, one can immediately select such secondary loads as will fall within the prescribed limits of accuracy of the transformer when operating under these conditions.

In the actual application of the results obtained from phase-angle and ratio measurements, it is customary to prepare a set of curves showing the variation from 0.1 load to full load under various conditions of impedance and power-factor in the secondary-connected load, together with a set of tables showing the correction factors to be applied for various values of B and various power-factors, both lagging and leading current, in the primary load.

While it is true the phase-angle seldom exceeds 1 degree in a well-designed transformer, errors as large as 10 per cent will result at power-factor 0.20 even under these conditions. It is

for this reason that phase-angle and ratio tests are so valuable. By referring to the table and curves, one can immediately select such conditions as will allow of a certain predetermined accuracy.

In conclusion it would be well to remark that the secondary of a current transformer should never be opened with current flowing in the primary; not only on account of the excessive voltage, but also because the flux in the core rises to such abnormal values that the iron is left in such condition as to change the magnetic constants, thereby affecting the magnetizing current and core loss, and, therefore, the ratio and phase-angle. For this reason, some manufacturers equip their current transformers with short-circuiting leads in order that the secondary may be short-circuited before taking the instrument out of circuit.

Sections and Branches

University of Arkansas Branch

The regular meeting of the University of Arkansas Branch was held on December 16, 1909. Professor G. E. Ripley, of the department of physics, read a paper on "The Source of Energy."

On January 6, 1910, Mr. R. Milwee abstracted Mr. H. L. Doherty's paper on "Development and Operation of Hydroelectric Plants." This was followed by brief papers on "Central Station Management", by Mr. R. W. Jones, and "Recent Installations", by Mr. S. B. Graham.

Armour Institute of Technology Branch

This Branch held its fourth meeting for the season on November 18, 1909. The subject discussed was Dr. Cary T. Hutchinson's paper on "The Electric System of the Great Northern Railway Company at Cascade Tunnel", which was abstracted by Mr. C. C. Bailey, who outlined the general considerations entering into the project. Others who took part in the discussion were, Messrs. Sherwin, Ruede, Williams, MacEwing and McCune. At the conclusion of the discussion Mr. Tellin gave a talk on the "Mallet Compound Engine."

At the meeting held on December 16, 1909, Mr. G. E. Marsh, of the electrical engineering department, gave a two-hour talk on "Wireless Telegraphy." Mr. Marsh introduced his subject with an explanation of ether vibrations, and described the distinguishing characteristics of the several classes of electromagnetic waves. He spoke at some length on the essential factors involved in the generation and reception of the waves used in wireless telegraphy, and explained the formation and transmission of wireless waves. The high-frequency resistance was contrasted with the steady-current resistance, and their relative magnitudes for various wires were given in tabular form. At the close of the lecture a few experiments were performed with oscillating currents, and a demonstration was made with a wireless telegraph outfit. The general discussion which followed the paper brought out several interesting problems. Mr. Marsh's lecture was based on data which he had previously taken up before meetings of the Hertzian Society.

Atlanta Section

At a meeting of the Executive Committee of the Atlanta Section held early in December the following officers were elected for the current year: Chairman, H. P. Wood; vice-chairman, E. P. Peck; secretary, M. E. Bonyun; managers, A. M. Schoen and J. R. Gordon. The regular December meeting of the Section was postponed.

Baltimore Section

The December meeting of the Baltimore Section was held on December 10, 1909. Mr. H. W. Rowley, of the Allis-Chalmers Company, gave a description of the "New York High-Pressure Pumping System." Mr. H. B.

Machen, assistant engineer of the New York High-Pressure Pumping System, gave a talk on the results obtained since the installation of the system, which was illustrated by colored lantern slides.

Boston Section

The Boston Section held its regular monthly meeting in the Edison Building on December 15, 1909. There was a total attendance of 113 persons. The meeting was preceded by an informal dinner at the United States Hotel. Mr. Paul Winsor, chief engineer of motive power and rolling stock, Boston Elevated Railway Company, presented a paper on "The Effect of Improvements in Old Types of Electrical Railway Equipment Maintenance." This was followed by a paper on "Power Station Economics", by Professor Ira N. Hollis, of Harvard University. A general discussion followed both papers.

Chicago Section

The Chicago Section held a joint meeting in conjunction with the Electrical Section of the Western Society of Engineers on December 22, 1909. The secretary announced the election of the following members of the Executive Committee: Chairman, J. G. Wray, secretary, E. N. Lake; Fay Woodmansee and W. B. Jackson, members for three years. The other members of the committee are, John D. Nies and W. L. Abbott. Mr. Ralph H. Rice, of the division of transportation and distribution of the Board of Supervising Engineers, Chicago, then presented a paper on "Low-Tension Feeder Systems for Street Railways." A large audience representing the railway and electrical power interests of Chicago was present. The paper was discussed by D. W. Roper, E. N. Lake and H. M. Wheeler.

University of Colorado Branch

The program of the meeting of this Branch held on December 1, 1909, was in the form of a debate on the question "Is Direct-Current of Greater Commercial Value than Alternating-Current." Each speaker was given a period of eight minutes, and each side a rebuttal of five minutes. Messrs. Beeler and Weber took the affirmative side, and Messrs. Robertson and Goldsborough the negative. Dr. O.C. Lester, and Messrs. Newton and DeReamer were the judges. The decision was given in favor of the affirmative side. Forty-two members were present.

University of Iowa Branch

This Branch was organized on October 18, 1909, with eight charter members. The following officers were elected: Chairman, H. E. Scheark; vice-chairman, E. H. Bailey; secretary-treasurer, A.H. Ford.

The first regular meeting was held on October 25, and the following papers were presented: "Why a Student Should be a Member of an Engineering Society", by Dean W. G. Raymond; "What is the American Institute of Electrical Engineers", by Professor A. H. Ford; "Historical Sketch of the American Institute of Electrical Engineers", by E. H. Bailey; "Development of the Incandescent Electric Lamp", by E. J. H. Wagner. Fifteen applicants were enrolled for membership at this meeting.

The following program was presented at the meeting held on November 8, 1909: A review of electrical periodicals for October, by O. L. Johnson; J. B. Taylor's paper on "Telegraph and Telephone Systems as Affected by Alternating-Current Lines", abstracted by E. R. Bowersox.

On November 22, 1909, Mr. E. B. Alcorn reviewed electrical periodicals for November. Mr. W. B. George presented a paper on "The Development of Artificial Illumination".

The meeting of December 13, 1909, was devoted to a review of electrical periodicals by Mr. D. M. Terwilliger,

and an abstract of Dr. Cary T. Hutchinson's paper on "The Electric System of the Great Northern Railway Company at Cascade Tunnel", by Mr. F. W. Jones.

Ithaca Section

Mr. H. L. Doherty's paper on "Comments on Development and Operation of Hydroelectric Plants" formed the main topic of discussion at the meeting of the Ithaca Section held on December 20, 1909. The paper was abstracted by Messrs. R. Olney and L. B. McBride. The abstracts were followed by a talk on "Estimation of Costs in Hydraulic Projects", by Professor F. J. Seery, of the College of Civil Engineering. Professor Seery analyzed the work of preparing estimates in detail, making allowance for labor conditions, transportation of material, excavation, etc. He recommended the plotting of estimates in graphical form as being more valuable and simple than many duplicate detailed calculations.

The Section expects to have as visitors in the near future Mr. Percy H. Thomas and Mr. Henry G. Stott. The annual dinner of the Section is to be held about the middle of February, and it is hoped that Mr. Stott can arrange his visit so as to be present at the dinner. The annual dinner has become an important feature in the work of the Section. This will be the third in the series.

University of Kansas Branch

At the regular meeting of the University of Kansas Branch, held on December 9, 1909, Mr. L. C. Mason, manager of the Lawrence, (Kansas) telephone exchange, gave a talk on "Telephone Disturbances and the Remedies." Mr. Cross reviewed current events in the electrical field from recent engineering magazines.

Lehigh University Branch

The regular December meeting of the Lehigh University Branch was held at the home of President H. S. Drinker, on Tuesday evening, December 14, 1909. Fifty-four members were present. The program consisted of three papers. The first was by Mr. A. J. Standing, on "Electrolytic Action", and dealt principally with the corrosion caused by stray electric currents from traction systems. In addition to considerable data regarding the destructive effects of these currents upon gas and water pipes, Mr. Standing also gave some results of tests of the action of alternating current on reinforced concrete. The second paper, by Mr. J. L. Farrar, on "Modern Electric Locomotives", gave a good description of the locomotives in use on the Pennsylvania Railroad, the New York, New Haven & Hartford Railroad, the New York Central, and the Great Northern Railway. The advantages of direct current and alternating current for different operating conditions were pointed out. Mr. Farrar stated that on the experimental track of the New York Central an electric and a steam locomotive were started under similar conditions of load, and the electric locomotive attained the speed of 60 miles per hour in one minute, as compared with two minutes for the steam locomotive. The last paper of the evening was presented by Mr. R. E. Brown, on "The Interpole Motor," and described the use of the motor for operating machine tools at high speed.

Lewis Institute Branch

The second meeting of the Lewis Institute Branch was held on December 14, 1909, the total attendance numbering 200 members and guests. The subject of the evening was a paper by Mr. George Strachan, on "The Street Lighting System of Chicago." Mr. Strachan spoke at length on the generation of the power at Lockport, Illinois, and its transmission from the station to Chicago. He described the various sub-stations and the methods of operation, and gave comparative statements as to their efficiencies. The sub-circuits were explained by means of diagrams, and the number of circuits, together

with the number of lamps per circuit were given. Line troubles, their causes and location were next discussed, and many interesting sources of trouble were brought out. Mr. Strachan, who has visited numerous cities in the United States and Canada, spoke highly of the street lighting system of Chicago.

Madison Section

The first meeting of the Madison Section for this season was held on December 16, 1909, 40 members being present. Officers were elected for the current year as follows: Chairman, M. H. Collbohm; secretary, H. B. Sanford; Executive Committee, the chairman, the secretary, and J. R. Price. Mr. M. H. Collbohm gave an abstract of Mr. H. L. Doherty's paper on "Development and Operation of Hydroelectric Plants." Professor Edward Bennett presented a paper on "Transmission Line Troubles." Both papers were followed by a general discussion.

Minnesota Section

The members of the Minnesota Section met at the offices of the Twin City Rapid Transit Company, Minneapolis, on December 20, 1909. At this meeting Mr. J. C. Vincent was elected chairman in place of Mr. Barry Dibble, resigned, and Mr. J. H. Schumacher was elected secretary. Mr. H. L. Doherty's paper on "Development and Operation of Hydroelectric Plants" was discussed.

University of Nebraska Branch

This Branch held its first formal meeting of the semester on December 14, 1909, in the lecture room of the electrical engineering department. An original paper on "Illumination and Illuminants" was presented by Professor George H. Morse. The paper covered the relative efficiencies of various sources of light, with special reference to electrical illuminants. For this meeting a very complete collection of lighting equipment had been loaned by various electrical companies, and served to illustrate each feature discussed. The lecture commenced with an experiment showing an electric arc of one foot in length between carbon terminals, drawn form a 9.8 direct-current arc circuit. This was followed by the projection upon a screen, of the image of a normal direct-current arc. Three flaming arc lamps, giving pearl-white, pink, and golden-glow light, were exhibited. A magnetite arc was then displayed in operation. The subject of incandescent lamps was next introduced by the glowing of a long platinum wire. A description was given, illustrated by means of lantern slides and specimens of the lamps themselves, of the various modern high-efficiency incandescent lamps, and the machinery, electric furnaces, hydraulic presses, etc., employed in their manufacture. Some stress was laid on the desire of the electrician to produce cold light, and a novel experiment bearing on this point was shown in the form of an exhausted bulb revolved at high speed by a motor. The bulb contained a phosphorescent mineral, which was caused to glow quite brightly by the application of pieces of paper to act as friction pads on the surface of the globe. The lecture closed with some experiments in high-frequency effects.

New Hampshire College Branch

A reorganization of this Branch was effected at a meeting held on December 13, 1909. Professor A. M. Buck, was elected chairman, and Mr. T. A. Thorp was elected secretary. Professor Buck then reviewed Dr. Cary T. Hutchinson's paper on "The Electric System of the Great Northern Railway at Cascade Tunnel." At the close of the ensuing discussion Professor Buck explained the advantages of affiliation with the Institute; and outlined the work of the Branch for the current year. There was an attendance of 15 members.

Pennsylvania State College Branch

The following officers were elected to hold office for three months, at a meeting of the Pennsylvania College Branch held on December 8, 1909: Chairman, H. H. Agee; vice-chairman, H. C. Meredith; secretary, H. E. Smith; treasurer, D. C. Ellinger; marshal, L. W. Parsons. Dr. Sparks, president of the college, then addressed the members on the subject, "How Can an Electrical Engineer Obtain a Polished Education." Arrangements have been made to have Mr. A. S. McAllister, of New York, deliver a series of lectures on electrical subjects in the near future.

Philadelphia Section

The Philadelphia Section held its regular monthly meeting in the Philadelphia Electric Building on December 13, 1909. Owing to the inclement weather the attendance was somewhat smaller than usual. A paper was presented by Mr. C. J. Russell on "Electro-Thermal and Electrochemical Development." It was discussed by Messrs. Hering, Snook, Hoadley, Kershner, Doherty, Costa, and Paynter.

President Lewis B. Stillwell, Secretary Ralph W. Pope, and Mr. W. S. Murray, of New Haven, were guests at the meeting held on January 10, 1910. The subject of this meeting was a paper presented by Mr. Charles E. Eveleth, of Schenectady, on "The Twelve-Hundred Volt Direct-Current Railway System." Messrs. Murray, Stillwell, Hewitt and Hoadley took part in the discussion. Mr. Stillwelll and Mr. Pope also addressed the meeting on Institute affairs. The attendance at the meeting numbered 120 members.

Pittsburgh Section

The December meeting of the Pittsburgh Section was held in the Carnegie lecture hall on December 14, 1909. A paper was given by Messrs. E. B. Tuttle and W. V. Read, of the Central District and Printing Telegraph Company, on "Telephone Transmission and the Oscillograph." Mr. Tuttle exhibited oscillograms showing the character of current-waves produced by different types of transmitters, and the effect of a cable in the subscriber's loop and in the inter-office trunk line. The phase-shift produced by a loaded cable was shown both for the current and voltage waves at the two ends of the circuit. Mr. Tuttle has succeeded in obtaining oscillograph curves of telephone speech-currents which are capable of accurate analysis. One point brought out in the paper was that the even harmonics are equally as important in speech-current waves as are the odd harmonics. The paper was discussed by Messrs. S. P Grace, R. A. L. Snyder, H. W. Fisher, and B. P. Rowe.

At the meeting held on January 11, 1910, Mr. Harold W. Brown presented an original paper on "Recent Designs in Electrical Measuring Instruments." Mr. Brown showed lantern slides illustrating the most recent designs of European and American indicating, recording and integrating meters, including instruments using electricity for other measurements. The practical advantages to the operator obtained by the revised designs were pointed out. The paper was followed by a lengthy discussion.

Pittsfield Section

Dr. A. E. Kennelly was the guest of the Pittsfield Section at a meeting held at the Wendell Hotel on December 21, 1909, and over 100 members were present to hear his address on "Mechanism of Wireless Telegraphy and Telephony." Dr. Kennelly explained the theory of transmission of wireless waves through space, and how the phenomenon, although so different from the ordinary forms of transmission of electric current through wires, may be explained by similar principles. In a dynamo electrical energy is transmitted or induced to the wires through the air gap in the magnetic field. In wire-

less telegraphy an electric wave is started in the region surrounding the antenna of a sending station due to the oscillation of the currents in the vertical mast. This wave travels along the surface of the earth in all directions at a speed equal to that of the velocity of light, becoming weaker as it spreads out. If in the progress of the wave the antenna of a receiving station is encountered, the electromotive force will be induced in it just as in the dynamo. The difference between the two is only of degree, the strength of the magnetic field in wireless telegraphy being extremely small in comparison with that of the dynamo. So far the greatest practical advantage gained by the development of wireless telegraphy has been at sea, whereby a vessel properly equipped may keep in constant communication with land. Dr. Kennelly concluded his address with some interesting speculations as to the sociological results of the introduction of wireless telegraphy.

One hundred and forty-seven members were present at the January meeting, held at the Wendell Hotel on January 13, 1910. The following papers were presented: "The Transformer, Its Early Development and Present State", by C. C. Chesney; "The Transformer in Service", by W. S. Moody; "Some Commercial Aspects of the Transformer", by L. R. Brown, of Schenectady; "Lightning Protection", by E. E. F. Creighton, of Schenectady.

Portland Section

The Portland Section met as usual in the Knights of Pythias Hall on December 22, 1909, with Mr. O. B. Coldwell presiding, and an attendance of 32 members. The subject of discussion was "Fire Underwriters' Service to the Public."

St. Louis Section

The fifty-second meeting of the St. Louis Section was held in the rooms of the Engineers' Club, at St. Louis, on December 8, 1909. Mr. George W. Lamke, of Washington University, delivered a lecture on "Illumination Calculations." The subject of photometric and illumination units was discussed at length, and followed by a discussion of the physiological effects of light. Standard methods of making illumination calculations were explained and the method of procedure followed by the speaker was given in detail. A new and original method for the determination of the spacing of light sources was also explained. Mr. Lamke commented briefly upon Holophane reflectors and the illuminating engineering rules governing the use of them. About 20 members heard the lecture.

San Francisco Section

The regular meeting of the San Francisco Section was held in the Home Telephone Company Building on December 17, 1909, a week earlier than usual, on account of the holidays. Mr. S. J. Lisberger, engineer of electric distribution, Pacific Gas & Electric Company, read a paper entitled "Underground Electric Construction." Mr. Lisberger's paper described the layout of underground systems. It dealt with the preliminary survey prior to installation, and the advisability as to whether the district, in the change from overhead to underground, should be made entirely alternating or direct current. Various features showing the advantages of the two systems were discussed in detail. The paper assumed an underground installation in a city of approximately 60,000 inhabitants, with alternating-current for lighting work, and 500-volt direct-current for power in the underground territory. Lantern slides were used to illustrate the standard types of manholes and service holes that have been adopted, and the forms and types of junction boxes for manhole use on both primary and secondary work. The paper also dealt with the class of work to be done in connection with the

service and types of construction necessary in cases where low and small buildings without basements were to be supplied from underground territory. Messrs. Holberton, Wilson, Worthington and McMeen took part in the discussion.

Schenectady Section

The fourth meeting of the Schenectady Section was held on Tuesday evening, December 14, 1909. At this meeting Dr. M. W. Franklin presented a paper on "Fixation of Atmospheric Nitrogen." While it has been known for over a century that nitrogen and oxygen combine during electrical discharges, it was not until 1898 that general interest in the subject was awakened by the announcement that laboratory experiments determined that the fixation of atmospheric nitrogen was a possibility. Dr. Franklin reviewed some of the experiments of scientists, made 10 years ago, when the prime reason for their researches was to obtain an artificial fertilizer for wheat-growing areas. In the light of recent scientific and electrical developments the necessity for nitric acid in the arts and sciences has become almost as important as the possibilities of nitrogen for fertilizing purposes. A brief description was given of several plants now in operation for the production of saltpetre from atmospheric nitrogen. The lecture was illustrated by stereopticon views. About 200 members were in attendance.

On January 4, 1910, the members were addressed by Mr. G. H. Hill, on "Problems Relating to the Electrification of Western Mountain Railroads." The various stages leading to the development of electric railways were reviewed by Mr. Hill. He then gave a history of the Union Pacific Railroad, which was built by the government under great difficulties about 50 years ago. Considerable time was also given to the electrification at the Cascade Mountain tunnel of the Great Northern Railway. Notwithstanding the extreme cold, over 300 members were present at this lecture.

Seattle Section

Mr. J. D. Ross, electrical engineer for the city of Seattle, addressed the members of the Seattle Section on December 18, 1909, at which meeting 53 members and guests were present. The subject of Mr. Ross' address was "The City Lighting Plant." He described the municipal electric lighting plant from the generating station at Cedar Lake to the distributing station in Seattle. The original installation comprised two 1,250 kw. generators connected to Pelton waterwheels. This has recently been enlarged by the installation of two 4,500 kw. units, direct-driven by turbines operating under 600-ft. head, making a total of 11,500 kw. for the present plant. The lecture was illustrated by a large number of lantern slides showing pipe-line construction, the power-house, the transmission line, and the sub-station. The paper was followed by a lengthy discussion by Messrs. Harisberger, Lindsay, Wickstrom, Evans, Miller, Ransom, Hoskins, and Moore.

Stanford University Branch

Eighteen members of this Branch met at the home of Professor H. J. Ryan on December 8, 1909. Professor Ryan gave a talk on "A Rapid Survey of the Electrical Industries." The principal object of the talk was to give the senior electrical engineers some idea of the opportunities and possibilities in the field of electrical engineering.

Syracuse University Branch

On the evening of January 13, 1910 the members of the Syracuse University Branch were addressed by Mr. H. J. Blakeslee, superintendent of the Bureau of Gas and Electricity of the city of Syracuse, on "Some Aspects of Electric Meter Testing." Mr. Blakeslee described the practice in testing watt-

hour meters by the Public Service Commission and by various companies, and some of the standard instruments used by the Syracuse Bureau of Gas and Electricity were shown. Mr. Blakeslee also explained the use of phantom loads for testing, and exhibited the phantom load designed by himself.

Toronto Section

The December meeting of the Toronto Section was held in the rooms of the Engineers' Club, Toronto, on December 17, 1909. Prior to the meeting about 50 members met at the St. Charles Café. for dinner. One hundred and nineteen members were present at the meeting, which was called to order at 8:30 p.m., with Mr. H. W. Price in the chair. After a few preliminary remarks, Mr. Price introduced Mr. P. W. Sothman, chief engineer of the Hydro Electric Power Commission of Ontario, who presented a paper on "The Hydro Electric Power Commission Distributing System." Mr. Sothman described minutely the proposed layout of the distribution system of the Commission, which comprises some 300 miles of 110,000-volt transmission. Numerous lantern slides were shown indicating the progress of the work at various stations along the line, and at the main station; at Niagara Falls and at Dundas. Photographs of construction work on the towers were shown, and a detailed description of the tests on the towers was given. Mr. Sothman also described the various tests made to determine the most desirable insulator for the system.

The Executive Committee of the Section met at the St. Charles Café on Tuesday afternoon, January 11, 1910, to discuss various matters relating to the work of the Section. Final arrangements were completed for the January meeting, at which Mr. Paul M. Lincoln, of Pittsburgh, was to be the guest. It was voted that the Executive Committee shall also constitute a membership committee, with a view to furthering an increase in the local membership. Mr. H. A. Moore was appointed the chairman of this committee. The manuscript of a paper on "The Tate Accumulator", by Harry L. Morrell, was submitted to the committee for consideration, and it was decided that after certain additions and modifications had been made in the paper it would be accepted for the April meeting. As the April meeting had originally reserved for a possible paper from Mr. E. E. F. Creighton, of Schenectady, it was decided that if Mr. Creighton can present a paper at that time, a special meeting of the Section will be called. A special committee was appointed to endeavor to secure the nomination of a Canadian member as one of the managers of the Institute. The members of the committee are: Messrs. W. A. Bucke, A. L. Mudge, W. H. Eisenbeis.

State College of Washington Branch

After a period of inactivity the State College of Washington Branch has been reorganized, and its first regular meeting for this year was held on January 7, 1910. Some important changes were made in the by-laws of the Branch. Hereafter meetings are to be held every two weeks. An abstract of Dr. Cary T. Hutchinson's paper on the "Electric System of the Great Northern Railway at Cascade Tunnel" was presented by Messrs. Finch and Henry. Many of the members persent had visited the tunnel, and several had been employed there during the summer vacation. The discussion which followed, therefore, was interesting. Professor M. K. Akers presided at this meeting, and there was an attendance of 40 members.

Worcester Polytechnic Institute Branch

The Worcester Polytechnic Institute Branch was addressed on the evening of December 17, 1909, by Mr. C. L. deMuralt, on the subject, "Modern

Developments in Heavy Electric Locomotives." Ninety members and friends attended the meeting. In introducing his paper Mr. de Muralt spoke of the historical development of the electric locomotive in this country, mentioning that the first electric railway installation of consequence was that of the Baltimore & Ohio Railroad Company at Baltimore, which was subsequently followed by the electrification of the New York Central and the New York, New Haven & Hartford railroad companies. In considering the construction features of electric locomotives Mr. de Muralt first gave his attention to the matter of side-rods. The side-rod, regarded as a disadvantage on the steam locomotive, was dispensed with on the first electric locomotives, but later it was seen to be a desirable feature, allowing a higher center of gravity, thus decreasing the strain on the rails and affording spring support to the locomotive motor. Lantern slides were shown to illustrate the structural features of the various types of locomotives and their respective parts, and figures were given to show the advantages of the induction motor over steam power for loads at high speed. The speaker concluded his address with a brief talk on the regenerative feature of the three-phase induction motor.

On January 7, 1910, Mr. Day Baker presented a paper on "The Advance of the Electric Vehicle." Mr. Baker commenced his talk with a brief historical sketch of the electric vehicle, showing by means of lantern slides some of the older types and various electric automobiles in use at the present time, principally of the runabout and single seat variety for city service. Passing on from pleasure vehicles, Mr. Baker spoke of the use of electric drays for heavy trucking, and gave a large number of illustrations of the application of these machines for this class of work. In all branches of industry this means of trucking has been found to be a great advantage over horse haulage, in regard to both cost and utility. He cited as an instance one firm which with a single electric dray, and extra battery, and a day and night crew, had replaced 14 dray horses and five wagons, with a saving in cost of 20 per cent. Tables of values showed the increase in capacity and utility of these machines, the speed, charging rates, and the life of the battery. At the conclusion of the talk Dr. Baker exhibited several storage cells of the common lead plate type, also one of the new Edison cells with steel electrodes.

Personal

MR. BION J. ARNOLD was married on December 22, 1909, to Mrs. Margaret Latimer Fonda, of New York City.

MR. J. R. WILSON, formerly manager of the Cleveland district office of the Crocker-Wheeler Company, has been transferred to the sales division at Ampere, N. J.

MR. WALTER W. GASKILL, having completed his studies in the engineering department of Harvard University, is now with the testing department of the General Electric Company at Schenectady.

MR. A. H. JESSUP has left the employ of the Sierra and San Francisco Power Company at Vallecita, Cal., and returned to Moscow, Idaho, to re-enter the University of Idaho.

MR. H. F. SANVILLE has removed from 1708 Sansom Street, Philadelphia, Pa., to rooms 608-609 Empire Building, corner of Thirteenth and Walnut Streets, Philadelphia.

MR. C. W. STONE, of Schenectady, gave a talk at the Engineer School, U. S. A., Washington Barracks, D. C., on January 12, 1910, on the subject, "Systems of Electrical Distribution."

MR. FREDERICK A. SPENCER has entered the employ of the Stone &

Webster Engineering Corporation. Previously Mr. Spencer was an assistant in electrical engineering in Harvard University.

Mr. C. B. Humphrey has severed his relations with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, to become vice-president of The White Investing Company, 43 Exchange Place, New York.

Mr. P. M. Haight, treasurer of the Sprague Electric Company, was recently elected president of the Electrical Trades Society of New York. Mr. Haight's experience promises for the society a successful administration.

Mr. John West Thompson has resigned the position of assistant engineer of the Mexican General Electric Company to become chief operating engineer of the Guanajuato Power and Electric Company, Guanajuato, Mexico.

Mr. Frank S. Hatch, resigned on November 1, 1909, his position as manager of the Bountiful Light and Power Company, to go with the High Creek Electric Light and Power Company, Richmond, Utah, as electrical engineer.

Mr. George M. Brill and Mr. Horace C. Gardner have formed a partnership under the name of Brill and Gardner, for the purpose of continuing the engineering and architectural practice heretofore conducted by Mr. Brill.

Mr. P. V. See has been appointed superintendent of car equipment, for the Hudson & Manhattan Railroad Company, New York. Mr. See was formerly with the Illinois Traction Company, as general foreman of the Decatur shops.

Mr. L. St. D. Roylance having resigned his position with the Bureau of Equipment, Navy Department, has resumed practice as consulting electrical and mechanical engineer, with offices at 82 Second Street, San Francisco, Cal.

Mr. L. P. Perry, who until recently was power engineer with The Connecticut Company at Waterbury, Conn., has accepted a similar position in the commercial department of the Narragansett Electric Lighting Company, of Providence, R. I.

Mr. T. A. Rhodes, Jr., formerly in the transmission department of the New York Central & Hudson River Railroad Company, has accepted a position with the Consolidated Gas, Electric Light and Power Company, Baltimore, Md.

Mr. Paul J. MacCutcheon recently resigned his position as manager of the New York office of the M. B. Foster Electric Company, electrical contractors and engineers. Mr. MacCutcheon has not announced his plans for the future.

Mr. Ernest Lunn, who for seven years was superintendent of storage batteries with the Commonwealth Edison Company, Chicago, Ill., has left that company to accept a position with the Firestone Tire & Rubber Company, Akron, Ohio.

Mr. O. W. Visscher, who has been in charge of the power apparatus sales department of the Philadelphia branch of the Western Electric Company, is now in charge of the electrical department of the Fairbanks-Morse Company's New York office.

Mr. W. I. Bell, who recently resigned his position as superintendent of the Marion power station, Public Service Corporation of New Jersey, Jersey City, has been appointed electrical engineer for the South Park Commissioners, Chicago, Ill.

Mr. Lloyd Lyon, until recently secretary of the Mobile Light and Railroad Company, resigned that position on January 15 to become treasurer of the Mexico Tramways Company and the Mexican Light and Power Company, Limited, City of Mexico, Mex.

Mr. P. J. Murphy has resigned his position as superintendent of power for the Coney Island and Brooklyn Railroad Company to take up work for Messrs. Ford, Bacon & Davis at San Francisco, Cal., in connection with the Sierra & San Francisco Power Company.

Mr. Harry Bindemann, electrical engineer, who until lately represented the Siemens Company of Berlin, Germany, in Havana, Cuba, has returned to his Berlin headquarters, after arranging with a well known firm to take over the Siemens-Schuchert Werke agency for Cuba.

Mr. Henry D. Jackson and Timothy W. Sprague, who carry on a general consulting engineering practice at 88 Broad Street, Boston, Mass., have admitted as an associate of the combine, Mr. Frederic H. Keyes, former general manager of the Robb-Mumford Boiler Company.

Mr. K. W. Endres, for nearly five years associated with the American Telephone and Telegraph Company as an engineer, is now connected with the New York office of the Western Electric Company as railway sales engineer in telephone train dispatching work.

Mr. R. H. Tillman, formerly associate engineer with the Rochester Railway & Light Company, Rochester, N. Y., resigned his position on December 1, 1909, and is now industrial engineer with the Consolidated Gas, Electric Light & Power Company of Baltimore, Md.

Mr. H. C. Eddy, former manager for the American District Steam Company, was elected on December 9, 1909, secretary and general manager of the Northern Heating & Electric Company, St. Paul, Minn. This company supplies electrical and steam heating service in that city.

Mr. F. J. Foote has been appointed master mechanic of the Ohio Electric Railway, Columbus, Ohio, vice D. A. Faut, resigned. Mr. Foote was previously connected with the installation and maintenance department of the Westinghouse Electric and Manufacturing Company.

Mr. George S. Lang has severed his connection as engineer and superintendent for the Andes Mining & Development Company, in Colombia, and is now vice-president and treasurer of the St. Louis Sales Company, with offices in the Chemical Building, St. Louis, Mo.

Mr. E. E. Turkington has left the Consolidated Electric Light Company of Portland Maine, to take a position as assistant electrical engineer in the inspection department of the Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

Mr. Louis F. Leurey, formerly electrical engineer with Sanderson and Porter on the Stanislaus development at Vallecita, Cal., has been transferred to San Francisco, Cal., as field foreman in the construction of the San Francisco sub-station for the Sierra & San Francisco Power Company.

Mr. L. R. Woodhull has severed his connection with the Bureau of Standards to accept a position with C. B. Thwing, manufacturer of electrical pyrometers. Mr. Woodhull assumed his new duties on January 1. His business address is 445 North Fifth Street, Philadelphia, Pa.

Mr. Earl Wheeler has resigned his position as director of the department of electrical and mechanical engineering, Engineer School, U. S. Army, to become electrical and mechanical engineer of the Electric Speedometer and Dynamometer Manufacturing Company, 1317–1319 New York Avenue, Washington, D. C.

Mr. H. C. Hoagland has accepted a position as special agent with H. M. Byllesby & Company, and is at present located at Muskogee, Oklahoma, investigating the water powers of the streams in that vicinity. Mr. Hoagland was formerly electrical and mechanical engineer for the Illinois Traction System.

Mr. Frederick D. Nims, former chief operating engineer for the Mexican Light & Power Company, Mexico, D. F., recently left Mexico to become electrical engineer for the Western Canada Power Company at Vancouver, B. C. This company is installing a large hydroelectric station at Stave Lake, about 40 miles from Vancouver.

Mr. Sydney F. Weston, for several years department agent of the International Sprinkler Company, has resigned to accept the appointment of manager of the New York district of the National Brake & Electric Company, 111 Broadway, New York, manufacturers of air brakes, air compressors and gasolene locomotives.

Mr. C. D. Haskins, of Schenectady, presented a paper before a representative audience of army officers at the Army War College, Washington Barracks, D. C., on " Electrical Engineering Education in the Army ", on Wednesday evening, January 12, 1910. Mr. Haskins proposed a new combined school for the instruction of technical officers of all technical corps.

Mr. Mortimer Freund, who for several years has been electrical aide to the consulting engineer and inspector of public works, U. S. Navy Yard, New York, has left the Navy Department to join the engineering staff of Mr. Percival T. Moses, consulting engineer, 43–45 West 34th Street, New York. Mr. Freund is a graduate of the school of engineering of Columbia University.

Mr. B. R. Shover, electrical engineer of the Indiana Steel Company during the design and construction of the company's plant at Gary, Indiana, has been transferred to the Youngstown district of the Carnegie Steel Company, at Youngstown, Ohio, where he will have charge of the design and construction of a number of motor-driven rolling mills which the United States Steel Corporation is erecting at Girard.

Mr. W. G. Thummel resigned his position on December 4, 1909, as locating engineer for the Toledo, St. Louis & New Orleans Railroad Company to take charge of preliminary and location surveys for the St. Louis County Belt Railroad Company, of St. Louis, from the northern terminus at Chain of Rocks, to the southern terminus at Jefferson Barracks. The road will be 30 miles in length.

Mr. L. S. Harmer, who for the past year has been in charge of electric power and new construction work of the Grandfather Falls Company, of Merrill, Wis., left that company on January 1, 1910, to begin work for the Menominee & Marinette Light & Traction Company. Mr. Harmer will superintend the installation of machinery at the company's new hydroelectric development on the Menominee River, and later will take charge of the plant.

Mr. Cyrus Avery Whipple, who recently was engaged in developing the power system of the U. S. Navy Yard at Bremerton, Wash., has resigned to accept the position of assistant electrical engineer of the British Columbia

Electric Railway Company, Limited, at Vancouver, B. C., in the construction of its Fraser Valley electric railway. This line extends up the Fraser Valley for 64 miles, and will provide passenger and freight service, also light and power to the towns along its route.

Discussion on H. L. Doherty's Paper on Hydroelectric Plants

In this issue of the PROCEEDINGS appears the complete discussion of Mr. Henry L. Doherty's paper entitled, "Comments on the Development and operation of Hydroelectric Plants", presented at the New York meeting of the Institute December 16, 1909. The High-Tension Transmission Committee, under whose auspices the paper was presented, invites further written discussion from any member who may be so inclined after having read the discussion printed herein. Such additional discussion should be submitted on or before April 10, 1910.

Obituary

MR. JOHN TRUMBULL MARSHALL, assistant engineer of the Edison Lamp Works at Harrison, N. J., died in Bermuda on January 1, 1910, at the age of 50 years. Mr. Marshall was born in Kingston, N. Y., and was graduated from the scientific department of Rutgers College in 1881. In October of the same year he entered the employ of the Edison Lamp Works. His first work was in connection with photometry and testing of lamps. In 1883 or 1884 he invented a comparison method of photometering lamps. By this method the voltage of a lamp at nominal candle-power is determined without the use of any electrical instrument by placing it in series with a lamp of known candle-power and voltage and observing their relative intensities. During the last few months Mr. Marshall completed and put in successful operation an improved method of comparison of lamp measurement known as the watts-per-candle photometer. Besides specializing in photometry, Mr. Marshall gave much attention to the manufacture of carbon filaments, especially methods of carbonization and of metallizing filaments in use at the present time. He became an Associate of the Institute on October 1, 1889, and on November 12, 1889 was transferred to the grade of Member.

MR. HENRY ELLIOT WAGGAMAN, of Washington, D. C., died last August. Mr. Waggaman was born on July 17, 1879. He was graduated from Princeton University in 1900 with the degree of C. E., and then took the electrical engineering course, graduating in 1902. He became an Associate of the Institute on January 27, 1905.

MR. ARTHUR PENN KENNEDY a Life Member of the Institute, was drowned at the dam of the Hillabee Gold Mining Company, Alexander City, Ala., on March 16, 1909. Mr. Kennedy was born on September 28, 1868, and was a graduate of Purdue University, Lafayette, Ind. In 1898 he had charge of the construction of a gold milling plant in Alabama. Subsequently he went to Maywood, Illinois, returning to Alabama in June 1903. At the time of his death he was electrical engineer with the Hillabee Gold Mining Company. He became an Associate of the Institute on April 26, 1899.

Library Accessions*

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Institute of Electrical Engineers. Year-Book 1910. New York, 1910.

American Railway Association. Proceedings of the Session held in Chicago, Nov. 17, 1909. Chicago,

*The Library Accession list published every month in the PROCEEDINGS includes additions to the library of the Institute only. Similar accession lists of the libraries of the American Institute of Mining Engineers and the American Society of Mechanical Engineers are published by those societies. Copies of these lists may be obtained without charge upon application to the secretary of the Institute.

1909. (Gift of American Railway Association.)

American Society of Agricultural Engineers. Transactions Vol. 1, No. 1. Madison, 1907. (Gift of American Society of Agricultural Engineers.)

Auto-Transformer Design. By A. H Avery. New York, Spon & Chamberlain, 1909. Price, $1.50 net. (Gift of publishers.)

CONTENTS:—Chapter I. Classification of Transformers II.—Modern Methods of Illumination. III.—Elementary Theory. Fundamental Formulæ. IV.—Practical Design. V.—Efficiency Calculations. VI.—Constructional Details.

Cambridge Bridge Commission. Report 1909. Boston, 1909. (Gift of Cambridge Bridge Commission.)

Ciencias Médicas e Higiene. Tomo I. (Volumen I de los Trabajos del Cuarto Congreso Cientifico (1° Pan-Americano) Santiago de Chile, 1909. (Gift of Comision 4° Congreso Cientifico.)

Columbia University. Catalogue and General Announcement, 1909–1910, New York, 1909. (Gift).

Contribution to the Statistics of International Electrical Engineering Symbology. By A. E. Kennelly. (Reprint from *Electrical World*, Aug. 12, 1909.) (Gift of author.)

Electric Cables: Their Construction and Cost. By D. Coyle and F. J. O. Howe. New York, Spon & Chamberlain, 1909. Price, $5.00 net. (Gift of Publishers.)

CONTENTS:—Chapter I.—Conductors. II.—Impregnated Paper Insulation. III.—Impregnated Jute Insulation. IV.—India-Rubber and Gutta-Percha. V.—Paper and Air Space Telephone Cable. VI.—Vulcanized Bitumen. VII.—Tapes and Braids. VIII.—Lead Sheath. IX.—Steel Wire Armour. X.—Steel Tape Armour. XI.—Labour, Charges and Examples. XII.—Complete Cables. XIII.—Miscellaneous.

L'Electricité dans les Mines-Applications Diverses—Extraction. By E. J. Brunswick, Paris, 1910. (Gift of Gauthier Villars.)

Engineers' Club of Toronto. Proceedings. Vol. I Toronto, 1909. (Gift.)

Equivalent Circuits of Composite Lines in the Steady State. By A. E. Kennelly (Proceedings American Academy of Arts & Sciences, Vol. 45, no. 3.) (Gift of author.)

Fuel Tests with House-Heating Boilers. (University of Illinois. Engineering Experiment Station. Bulletin No. 31.) By J. M. Snodgrass. Urbana, 1909. (Gift.)

Linear Resistance Between Parallel Conducting Cylinders in a Medium of Uniform Conductivity. By A. E. Kennelly. (Gift of author.)

McGraw Electrical Directory. October, 1909. New York, 1909. (Gift.)

New York State Public Service Commission, 2d District Matter of the Complaint of R. B. Rock Against the Delaware and Hudson Company. Opinion of the Commission Dec. 2, 1909. (Exchange.)

——Matter of the Complaint of the New York State Shippers Protective Association, Incorporated, against the New York Central and Hudson River Railroad Company, etc. Opinion of the Commission. Nov. 4, 1909. (Exchange.)

——Passenger Train Delay Bulletin No. 18, Sept. 1909. (Exchange.)

Primer of Explosives for Coal Miners. (Bulletin no. 423, U. S. Geological Survey.) By C. E. Munroe and C. Hall. Washington, 1909. (Gift.)

Royal Society of London. Catalogue of Scientific Papers 1800–1900. Subject Index. Volume II. Mechanics Cambridge, 1909. (Gift of E. D. Adams.)

Standard Wiring for Electric Light and Power. Edition 16. By H. C. Cushing, Jr. New York, 1910. (Gift of author.)

The author has, with his collaborators, compiled this little volume of 157 pages to set forth, and explain, as clearly as possible, the essential rules and requirements for safe and economical exterior and interior electric light and power wiring and construction with an effort to standardize, as much as possible, all work of this nature.

Submarine Signal Bulletin No. 36. Boston, 1909. (Gift.)

Switchboard Measuring Instruments for Continuous and Polyphase Systems. By J. C. Connan. New York, Spon & Chamberlain, 1908. (Gift of publishers.) Price, $2.00.

CONTENTS:—Chapter I.—Definitions of Terms and Principles of Construction. II.—Remarks on Material, Construction and Characteristics of Various Parts. III.—Type A Instruments: Magneto-Dynamic Principle, Moving Coil System. IV.—Type B_1 Instruments: Electro-Dynamic Principle, Moving Coil System. V.—Type B_2 Instruments: Electro-Dynamic Principle, Induction System, Shifting Field Class. VI.—Type B_2 Instruments: Electro-Dynamic Principle, Induction System Rotating Field Class. VII.—Type C Instruments: Electro-Magnetic Principle, Moving Iron System. VIII.—Type D Instruments: Electrothermic Principle, Hot Wire System. IX.—Type E Instruments: Electrostatic Principle, Moving Vane System. X.—Type F Instruments: Resonance Principle, Vibrating Reed System.

Tests of Run-of-Mine and Briquetted Coal in a Locomotive Boiler. (Bulletin no. 4–12 U. S. Geological Survey.) By W. T. Ray and H. Kreisinger. Washington, 1909. (Gift.)

U. S. Steam Engineering Bureau, Annual Report. 1909. Washington, 1909. (Gift.)

U. S. War Department. Report of the Chief Signal Officer U. S. Army, 1909. Washington, 1909. (Gift.)

GIFT OF MR. T. C. MARTIN

——Broca, A., La Telegraphie sans fils. Paris, 1899.

——Claude, G. L'Electricité a la Portée de Tout la Monde. Paris, 1905.

——Courmelles, Foveau de. L'Année Electrique. Revue de 1903. Paris, 1904.

——Dumont, G. Automobiles sur Rails. Paris, n.d.

——Dupuy, Paul. Traction Electrique. Paris, 1903.

——Estaunie, Edouard. Traite Pratique de Télécommunication Electrique. Paris, 1904.

——Rodet, J. Les Lampes a Incandescence Electriques. Paris, 1907.

——Sencier, G. & Delasalle, A. Automobiles Electriques. Paris, 1901.

——Turpain, A. Les Applications Pratiques des Ondes Electriques. Paris, 1902.

——Vivarez, H. Phènomènes Electriques et Leurs Applications. Paris 1901.

UNITED ENGINEERING SOCIETY

Index to economic material in documents of the states of the United States. Maine, 1820–1904; Massachusetts, New Hampshire, New York, Rhode Island, Vermont, 1789–1904. By A. R. Hasse. Washington, 1907–1908. (Purchase.)

Manufacturers' Record's Annual Blue-Book of Southern Progress 1909. Baltimore, 1909. (Gift of Manufacturers' Record.)

Illustrations of Concrete steel arch bridges. (Gift of Concrete Steel Engineering Company.)

TRADE CATALOGUES

Allgemeine Elektricitäts - Gesellschaft, Berlin, Ger. Single and polyphase turbo-dynamos. 40 pp.

——Turbo-driven auxiliary machines for power stations, centrals, and marine engines. 42 pp.

——A. E. G. arc lamps, using T. B. carbons. 4 pp.

Dielectric Company of America, Belleville, N. J. Dielectric system of underground transmission for power and lighting circuits. 15 pp.

General Electric Co., Schenectady, N. Y. Bulletin No. 4684 on parts of form D luminous arc headlight. 4 pp.

——Bulletin No. 4708, Thomson direct current test meter, type CB-3. 4. pp.

——Bulletin No. 4709—Portable instruments, type P-3. 9 pp.

Pettingell-Andrews Co., Boston, Mass. Juice, January 1910, devoted to the interests of electric supplies and electric lighting fixtures, manufactured by the Company. 16 pp.

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INSTITUTE REPRESENTATIVES.

(Revised to January 1, 1910)

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LIST OF SECTIONS.

(Revised to January 1, 1910.)

Name and when Organized		Chairman.	Secretary.
Atlanta	Jan. 19, '04	H. P. Wood.	M. E. Bonyun, G. E. Co., Atlanta, Ga
Baltimore	Dec. 16, '04	J. B. Whitehead.	L. M. Potts, 107 East Lombard St., Baltimore, Md.
Boston	Feb. 13, '03	D. C. Jackson.	A. L. Pearson, 93 Federal St., Boston, Mass
Chicago	1893	W. L. Abbott.	J. G. Wray, 203 Washington St., Chicago. Ill.
Cleveland	Sept. 27, '07	H. L. Wallau.	F. M. Hibben, 807 The Cuyahoga Bldg., Cleveland, O.
Fort Wayne	Aug. 14, '08	E. A. Wagner.	J. V. Hunter, Fort Wayne Electric Works. Ft. Wayne, Ind.
Ithaca	Oct. 15, '02	E. L. Nichols.	B. C. Dennison, Cornell University Ithaca, N. Y.
Los Angeles	May 19, '08	J. A. Lighthipe.	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Madison	Jan. 8, '09	M. H. Collbohm	H B. Sanford, Univ. of Wisconsin, Madison, Wis.
Mexico	Dec. 13, '07	E. Leonarz.	W. A. Ferguson, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota	Apr. 7, '02	J. C. Vincent	J. H. Schumacher, 2716 University Ave., Minneapolis, Minn.
Norfolk	Mar. 13, '08		R. R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia	Feb. 18, '03	Geo. A. Hoadley.	H. F. Sanville. 608 Empire Building. Philadelphia, Pa.
Pittsburg	Oct. 13, '02	C. B. Auel.	E. B. Tuttle, C. D. & P. Tel. Co., Pittsburgh, Pa
Pittsfield	Mar. 25, '04	H. W. Tobey.	L. F. Blume, G. E. Co., Pittsfield, Mass.
Portland, Ore	May 18, '09	O. B. Coldwell.	L. B. Cramer, 720 Corbett Building, Portland, Ore.
San Francisco	Dec. 23, '04	George R. Murphy.	S. J. Lisberger, 445 Sutter St., San Francisco, Cal.
Schenectady	Jan. 26, '03	M. O. Troy.	R. H. Carlton, Gen. Elec. Co., Schenectady, N. Y.
Seattle	Jan. 19, '04	J. H. Harisberger.	George Holmes Moore, City Engineer's Office, Seattle, Wash.
St. Louis	Jan. 14, '03	A. S Langsdorf.	George W. Lamke, Washington University, St. Louis, Mo.
Toledo	June 3, '07	M. W. Hansen.	Geo. E. Kirk, 1649 The Nicholas, Toledo, O.
Toronto	Sept. 30, '03	H. W. Price.	W. H. Eisenbeis, 1207 Traders' Bank Bldg., Toronto, Can.
Urbana	Nov. 25, '02	Charles T. Knipp.	J. M. Bryant, 610 West Oregon St., Urbana, Ill.
Washington, D. C.	Apr. 9, '03	Philander Betts.	M. G. Lloyd, Bureau of Standards, Washington, D. C.

Total, 24.

LIST OF BRANCHES.

(Revised to January 1, 1910.)

Name and when Organized.	Chairman.	Secretary.
Agricultural and Mechanical College of Texas............Nov. 12, '09		
Arkansas, Univ. of..Mar. 25, '04	W. B. Stelzner.	F. S. White, 523 Willow St., Fayetteville, Ark.
Armour Institute...Feb. 26, '04	Edward Sherwin.	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Case School, Cleveland.............Jan. 8, '09	C. N. Weems.	S. G. Hibben, 2171 Cornell St., Cleveland, O.
Cincinnati, Univ. of..Apr. 10, '08	C. R. Wylie.	Ralph B. Kersay, 315 Jackson St., Carthage, Ohio.
Colorado, Univ. of...Dec. 16, '04	E. A. Robertson.	A. P. Sunnergren, 1209 Penn., Boulder, Colo.
Iowa State College...Apr. 15, '03	F. A. Fish.	Adolph Shane, Iowa State College, Ames, Ia.
Iowa, Univ. of.......May 18, '09	H. E. Scheark.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col. Jan. 10, '08	R. E. Talley.	B. F. Eyer, 513 Fremont St., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	V. S. Foster.	R. L. Ponsler, Univ. of Kansas, Lawrence, Kans.
Lehigh University....Oct. 15, '02	W. W. Broadbent	Howard M. Fry, Lehigh University, Bethlehem, Pa.
Lewis Institute.......Nov. 8, '07	Frank Burch.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Michigan, Univ. of...Mar. 25, '04	E. B. McKinney.	Gerald J. Wagner, 454 S. First St., Ann Arbor, Mich.
Missouri, Univ. of....Jan. 10, '03	H. B. Shaw.	A. E. Flowers, Univ. of Missouri, Columbia, Mo.
Montana State Col...May 21, '07	C. C. Kennedy.	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of...Apr. 10, '08	Geo. H. Morse.	V. L. Hollister, Station A, Lincoln, Nebraska.
New Hampshire Col..Feb. 19, '09	A. M. Buck.	T. A. Thorp, New Hampshire College, Durham, N. H.
Ohio State Univ......Dec. 20, '02	G. A. Arnold.	E. C. Williamson, 181 West 8th Ave., Columbus, O.
Oregon State Agr. Col. Mar. 24, '08	E. R. Shepard.	W. Weniger, Ore. State Agricul. College, Corvallis, Ore.
Penn. State College...Dec. 20, '02	H. H. Agee.	H. E. Smith, Penn. State College, State College, Pa.
Purdue Univ.........Jan. 26, '03	J. W. Esterline.	H. T. Plumb, Purdue University, Lafayette, Ind.
Rensselaer Polytechnic Institute.......Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y.
Stanford Univ.......Dec. 13, '07	C. L. Bradley.	C. P. Taylor, Stanford University, California.
Syracuse Univ.......Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of......Feb. 14, '08	B. E. Kenyon.	J. A. Correll, University of Texas, Austin, Tex.
Wash., State Col. of..Dec. 13, '07		M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ....Feb. 26, '04	H. F. Thomson.	George W. Picksen, Washington University, St. Louis, Mo.
Worcester Poly. Inst..Mar. 25, '04	Ray H. Taber.	C. E Putnam, Worcester Poly. Inst., Worcester, Mass

Total, 28.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

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THE EDITING COMMITTEE

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Vol. XXIX **March, 1910** No. 3

March Meeting of the Institute, March 11, 1910

The regular March meeting of the American Institute of Electrical Engineers will be held in the Engineers' Building, 33 West 39th Street, New York City, on Friday, March 11, 1910. The papers to be presented at this meeting are as follows: " Electric Mine Hoists ", by D. B. Rushmore and K. A. Pauly; " Electric Mine Hoists ", by W. Sykes; " Electric Mine Hoists with Ilgner Motor Generator Set ", by R. R. Seeber. As these papers will be of especial interest to mining engineers, members of the American Institute of Mining Engineers are cordially invited to attend this meeting.

Institute Meeting at Charlotte, N. C., March 30-April 1, 1910

The attention of the Institute membership is again directed to the meeting to be held at Charlotte, N. C., on March 30, 31 and April 1, 1910. The official headquarters will be at the Selwyn Hotel, which is on the European plan. Other hotels in Charlotte are: Buford Hotel, American and European plan; Stonewall Hotel, European plan; Central Hotel, American plan.

The technical program as now arranged will be about as follows:

" Economics of Hydroelectric Plants ", by W. S. Lee.

" Electric Drive in Textile Mills ", by A. Milmow.

" Gas Engines in City Railway and Light Service," by E. D. Latta, Jr.

" A Method of Protecting Insulators from Lightning and Power Arc Effects with Results of its Installation on the Lines of the Niagara and Lockport Power Company ", by L. C. Nicholson.

" Modifications of Hering's Laws of Furnace Electrodes ", by A. E. Kennelly.

" Some Demonstrations of Lightning Phenomena " by E. E. F. Creighton, illustrated by experiments.

The local Committee on Arrangements has arranged for a number of pleasing social features, and several interesting excursions to power plants and cotton mills. This being the first meeting of its kind to be held by the Institute, it is hoped that as many members as can possibly attend will be present, and thus contribute to its success.

Meeting A. I. E. E., April 8, 1910

The two hundred and forty-fifth meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Friday evening, April 8, 1910. The meeting is to be held under the auspices of the Educational Committee. Dr. Samuel Sheldon, professor of physics and electrical engineering in the Brooklyn Polytechnic Institute, will present a paper entitled " Education for Leadership in Electrical Engineering." The paper will appear in the April PROCEEDINGS.

Institute Meeting at San Francisco, April 21, 22 and 23, 1910

As announced in the February PROCEEDINGS, a meeting of the Institute under the auspices of the High-Tension Transmission Committee will be held in San Francisco, Cal., on April 21, 22 and 23, 1910. Papers thus far promised for this meeting are as follows:

"The Economics of a General Power System", by John A. Britton.

"The Developed High-Tension Network of a General Power System", by Paul M. Downing.

"Hydroelectric Development and Irrigation", by John Coffee Hays.

"Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants Under Pacific Coast Conditions", by A. M. Hunt.

The Local Committee is making arrangements for entertainment and side trips, the latter with reference to inspection of some of the important transmission work on the coast.

Meeting of A. S. M. E. and Boston Section, A.I.E.E., March 11, 1910

The American Society of Mechanical Engineers will hold a meeting in cooperation with the Boston Section of the American Institute of Electrical Engineers on Friday evening, March 11, 1910, in Room 6, Lowell Building, Massachusetts Institute of Technology, Boston. A paper entitled "The Training of Men—A Necessary Part of a Modern Factory System" will be presented by Mr. M. W. Alexander, of Lynn, Mass. This paper will describe in detail the work which the General Electric Company is doing at Lynn in the way of training young men to become shop foremen, superintendents, etc., and will be of interest to engineers generally.

A. I. M. E. Convention, Pittsburgh, March 1 to March 4, 1910

The American Institute of Mining Engineers will hold its convention in Pittsburgh, Pa., from March 1 to March 4, 1910. The members of the American Institute of Electrical Engineers have been cordially invited to attend the convention, and will be welcomed at the professional sessions and such other functions as may be planned. The A. I. M. E. headquarters will be at the Hotel Schenley, and the sessions will be held in the Carnegie Library, opposite the hotel. A number of interesting excursions have been arranged for. There will be a trip to the steel plant at Homestead, occupying one day, and an afternoon will be given over to a visit to the testing station of the U. S. Geological Survey, where special tests will be made to show the effect of various explosives on mine gases. Some tests will also be made on reinforced concrete. A tour of inspection of various manufacturing plants is also contemplated, and arrangements will probably be made for a visit to a coal mine. The secretary of the Local Committee is Mr. Harrison W. Craver, Carnegie Library, Pittsburgh, to whom all inquiries concerning local matters and arrangements for the meeting should be addressed

Joint Meeting at Boston, January 21, 1910

A joint meeting of engineers was held in Boston on January 21, 1910. The organizations participating were: Boston Section of the American Institute of Electrical Engineers, American Society of Mechanical Engineers and the Boston Society of Civil Engineers. The attendance numbered approximately 450 members of the various societies. The technical part of the program consisted of a stereopticon lecture on "The Main and Auxiliary Machinery of the North Dakota," by Mr. Charles B. Edwards, the designer of the great battleship's turbines. The lecture was one which would interest not only engineers, but non-technical men as well. The North Dakota was selected by Mr. Edwards for the purpose of pointing out some of the engineering

problems confronting naval designers of modern battleships. The battleship and its machinery were fully described, a stereopticon serving to illustrate the various parts. At the conclusion of the lecture, brief addresses were made by Professor Ira N. Hollis, Mr. George B. Francis, Mr. John A. Bensil, Mr. Lewis B. Stillwell, Mr. R. Clipston Sturgis, Honorable Charles F. Adams, Mr. George Westinghouse, Professor D. C. Jackson, Mr. I. E. Moultrop, and Mr. C. S. Clark. In the course of his remarks, Mr. Francis, as president of the Boston Society of Civil Engineers, the oldest engineering society in the country, outlined a plan for an engineers' club for the allied societies in Boston and its vicinity, and a motion was adopted to appoint a committee of representatives of the various societies to mature plans for the project.

Boston Institute Meeting February 16, 1910

The meeting of the Institute in Boston, authorized by the Board of Directors, was held in the auditorium of the City Club on February 16, 1910. Arrangements were made by the officers and committees of the Boston Section with the coöperation of the local members of the American Society of Mechanical Engineers. An informal dinner at the club, preceding the meeting, was participated in by 250 members and guests, while about 500 attended the meeting, which was called to order at 8 o'clock by Professor Dugald C. Jackson, chairman of the Boston Section. Secretary Pope was called upon to make an announcement which related to the coming meeting of the Institute at Charlotte, N. C., which he said offered another opportunity for the officers and members of the various Sections and Branches to meet. Chairman David B. Rushmore of the Industrial Power Committee was then introduced, and took charge of the meeting. The five papers printed in the February PROCEEDINGS were read in abstract, all being presented in the course of an hour. The papers were thoroughly and intelligently discussed, there being present able participants upon each side of the principal question at issue, which was given as the subject of Charles T. Main's introductory paper, "Central Stations versus Isolated Plants for Textile Mills." The meeting was successful in every way, and an indication of the wisdom of joint efforts of engineers in all branches getting together and discussing topics of general interest. Mr. I. E. Moultrop, representing the American Society of Mechanical Engineers, announced the calling of a similar meeting upon another subject, the arrangements for which would be made by the local representatives of that society. The meeting will be held on Friday evening, March 11, at the Massachusetts Institute of Technology, and members of all the national engineering societies are invited to attend.

Founder Societies Dinner

On Thursday evening, February 17, 1910, the governing boards of the United Engineering Society, American Society of Mechanical Engineers, American Institute of Mining Engineers and the American Institute of Electrical Engineers dined together at the Engineers' Club, for the purpose of extending acquaintanceship, and informally discussing future plans for the general welfare. Thirty-four representatives of past and present governing boards attended. Past-President Henry G. Stott, the newly elected president of the trustees of the United Engineering Society, officiated as chairman, and introduced Past-President Lieb, treasurer of the United Engineering Society, who gave an abstract of his recent annual report and called attention to the fact that practically all of the available office space in the Engineers' Building has now been allotted to various associate societies. Among the speakers who followed were Messrs. F. J. Miller,

R. W. Raymond, Calvert Townley, A. R. Ledoux, F. R. Hutton, C. F. Scott, S. S. Wheeler, and T. C. Martin. General satisfaction was expressed with the successful administration of the affairs of the United Engineering Society during the three years' experience in the occupation of the Engineers' Building

New Board of Trustees United Engineering Society

In accordance with the by-laws of the United Engineering Society, three members of its Board of Trustees were retired at the annual meeting of the Board held on January 27, 1910, after completion of their three-year term. Dr. Samuel Sheldon was the retiring member representing the American Institute of Electrical Engineers, and he was succeeded by President Lewis B. Stillwell, who had been elected to fill the vacancy at the meeting of the Institute Board of Directors held on January 14, 1910. The three representatives of the Institute on the Board of Trustees now are: Messrs. H. G. Stott, Louis A. Ferguson, and Lewis B. Stillwell. Mr. H. G. Stott was unanimously elected president of the Board.

At the meeting February 24, Dr. Joseph Struthers was elected Treasurer.

New Section at Milwaukee

In response to a petition received from the Institute members in Milwaukee, Wis., the Board of Directors at its meeting held on February 11, 1910 authorized the formation of a Section in that city, to be known as the Milwaukee Section. Besides 72 Institute members, there is in Milwaukee and its immediate vicinity a large number of young engineers, many of them graduates from universities and colleges, who are not yet affiliated with any engineering society. It is believed that these men will become interested in the work of the Section, and the indications are that the Institute will have a very active local organization at Milwaukee.

New University Branches

At the meeting of the Institute Board of Directors on February 11, 1910, authorization was granted for the establishment of a Branch at The State Agricultural College, Fort Collins, Colo.

At the same meeting of the Board, a Branch was authorized at The North Carolina College of Agriculture and Mechanic Arts, West Raleigh, N. C. The organization has since been effected by the election of the following officers: Chairman, William Hand Browne, Jr., secretary, E. B. Moore; treasurer, C. R. Jordan.

Directors Meeting, February 11, 1910

The regular monthly meeting of the Institute Board of Directors was held at 33 West 39th Street, New York City, on Friday, February 11, 1910. The directors present were: Past-President Henry G. Stott, New York; Vice-Presidents C. C. Chesney, Pittsfield, Mass., Bancroft Gherardi, New York, Calvert Townley, New Haven, Conn., Paul M. Lincoln, Pittsburgh, Pa., Managers H. W. Buck, New York, Percy H. Thomas, New York, David B. Rushmore, Schenectady, N. Y., W. G. Carlton, New York, A. W. Berresford, Milwaukee, Wis., Severn D. Sprong, New York, Ralph W. Pope, Elizabeth, N. J.

Seventy-five candidates for admission to membership in the Institute as Associates were elected, as per list printed elsewhere in this issue.

Fifty-three Students were ordered enrolled.

Three Associates were transferred to the grade of Member, as follows:

Barton R. Shover, electrical engineer, Indiana Steel Company, Gary, Indiana.

Morton Arendt, instructor in electrical engineering, Columbia University, New York.

Putnam A. Bates, consulting electrical engineer, 2 Rector Street, New York.

Associates Elected February 11, 1910

ADAMS, EDWARD DEAN, Banker, 71 Broadway; res., 455 Madison Avenue, New York City.

ALLEN, JOHN SAMUEL, Manager, Equitable Electric Light Company, Lake Geneva, Wisconsin.

ARNOTT, THOMAS FREDERICK, Quartermaster Electrician, Navy Yard, Puget Sound; res., Charleston, Wash.

ANDERSON, RICHARD TERHUNE, Mechanical Engineer, Crocker-Wheeler Co., Ampere; res., 28 High Street, Passaic, N. J.

ANTHONY, ROWLAND BARNEY, The Bristol Company, 1670 Frick Bldg., Annex, Pittsburg, Pa.

BADEAU, HARRY U., Electrical Engineer, Bryant Electric Company, Bridgeport, Conn.

BALL, ALEXANDER WILLIAM, Chief Engineer, Texarkana Gas and Electric Co., Texarkana, Texas.

BARNETT, JOHN WINFIELD, Chief Electrician, New York and Honduras Rosario Mining Co., San Juancito, Honduras, C. A.

BILLINGS, WARREN CHESBRO, Assistant to Electrical Engineer, Bangor Railway & Electric Co., Bangor, Maine.

BROWN, EUGENE CLARE, Patent Lawyer Victor Building, Washington, D. C

CARLEY, RALPH F., Supt. Railway Dept. Galesburg Railway & Light Co., Galesburg, Illinois.

CASS, ROBERT MILLES, Electric Engineer, The Indianapolis Light & Heat Co., Indianapolis, Indiana.

CHRISTIANSEN, CONRAD EMIL, Electrical Engineer, Toledo Light, Power and Mfg. Co., Toledo, Oregon.

CODY, FRANK LINDUS, Manager, The Cobalt Light, Power & Water Co., Ltd., Cobalt, Ontario.

COLLINGHAM, ROBERT HUGH, Testing Department, British Thomson-Houston Co., Ltd., Rugby, England.

COMMERFORD, JAMES WILLIAM, JR., Manager and Proprietor, Electrical Wiring Fixture & Supply Co., 261 College St., Toronto, Can.

CONNETTE, EDWARD G., Transportation Engineer, Public Service Commission, 1815 Tribune Building, New York City.

DEWEY, FRED SUMNER, Assistant Superintendent, Peoples Light Company; res., 1108 Harrison St., Davenport, Iowa.

DRAKE, WILLIAM THOMAS, Instructor, Electrical Engineering Polytechnic College of Engineering, Oakland; res., 1711 Woolsey St., Berkeley, Cal.

FLOOD, HENRY, JR., Mechanical Engineer, Newburgh Light, Heat & Power Co., Newburgh, N. Y.

FRANZ, JOSEPH, Superintendent of Construction, Rogers Electric Company, Lenox, Mass.

FULTON, ROBERT ANSON, Cleveland Electric Illuminating Co.; res., 334 East 124th Place, Cleveland, Ohio

GILLES, RICHARD LESTER, Manager Electrical Repair Dept., Northern Pacific R.R. Co., St. Paul, Minn.

GOLDBERG, MAXIMILIAN MEIER, Assistant in Physics, Cornell University; res., 115 Stewart Ave., Ithaca, N. Y.

GREEN, CHARLES WILLIAM, Instructor in Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass.

GROVE, WILLIAM HOWARD, Contracting Electrical Engineer, Bodine & Grove, Williamstown, N. J.; res., 4321 Walnut St., Philadelphia, Pa.

HAWKINS, ARCHIE VINCENT, Solicitor, Potomac Electric Power Company, 213 14th St. N. W., Washington, D. C.

HAWKINS, HARRY CLYDE, Assistant Engineer, Mexican General Electric Co., Mexico City, Mex.

HESCH, HENRY C., The Telluride Power Company, Provo, Utah.

HILL, JACK B., Instructor in Electrical Engineering, University of Iowa, Iowa City, Iowa.

HOWARD, ARTHUR JAMES, Electrical Engineer, A. L. Swett Electric Light & Power Co., Medina, N. Y.

HULETT, GEORGE AUGUSTUS, Professor of Physical Chemistry, Princeton University, Princeton, N. J.

JACOBUCCI, JOSEPH HARRY, Supt. of Power Plant, Williams Electric Supply Co., Rawlins, Wyoming.

JENSEN, HAY, Electrical Engineer, Siam Electricity Co., Ltd., Bangkok, Siam.

JETER, GEORGE GUY, Student, University of Illinois; res., 806 West Green St., Urbana, Ill.

JOHNSON, WILLIAM S., Assistant in Electrical Engineering Dept., Pacific Light & Power Co., Los Angeles, Cal.

JONES, BASSETT, JR., Consulting Electrical Engineering, with Henry C. Meyer, Jr., 1 Madison Ave., New York City.

JONES, HAMILTON MCRARY, Assistant Chief Electrical Engineer, Guanica Centrale, Ensenada, Porto Rico.

JONES, WILLIAM WALTER, Assistant Engineer, General Electric Co., 30 Church Street, New York City.

KAHLER, CHARLES PORTERFIELD, Assistant Engineer, Oregon Short Line Railroad and Southern Pacific Co., Salt Lake City, Utah.

KENNEDY, ALEXANDER, JR., Tester, General Electric Co., Schenectady, N. Y.

KIDD, JOHN WILLIAM, Associate Professor of Physics, The Agricultural and Mechanical College of Texas, College Station, Texas.

LEMBECK, ARTHUR WALTER, Representative, Westinghouse Electric & Mfg. Co., 212 S. W. Temple St., Salt Lake City, Utah.

MCLAUGHLIN, JOHN CHARLES, Chief Clerk, Potomac Electric Power Co., Washington, D. C.

MOYER, HERBERT C., Student, General Electric Co.; res., 86 Mall St., West Lynn, Mass.

NAUHEIM, SAMUEL ALBERT, Draftsman, Interborough Rapid Transit Co., 98th St. & 3rd Ave., New York City.

NELSON, ALBIN AUGUST, Switchboard Attendant, Montana Indiana Telephone Co., Butte, Mont.

OWENS, JAMES WHITFIELD, Draftsman, Pennsylvania Railroad, 10 Bridge Street, New York City.

PARKER, CHARLES HAMILTON, Assistant Superintendent Generating Dept., Edison Electric Illuminating Co., Boston, Mass.

PATTEN, HARRY C., D. C. & Wm. B. Jackson, Boston; res., 205 Savin Hill Ave., Dorchester, Mass.

PEASLEE, WILLIS DHU AINE, Student, Leland Stanford Jr. University, Stanford University, Cal.

PERRIN, LOUIS MACKENZIE, Draftsman, Southern Pacific Co., 1117 Flood Bldg., San Francisco, Cal.

PERRINE, WILLIAM JOHN, Assistant Manager and Chief Electrician, City Electric Lighting Co., Vincennes, Ind.

POPE, HERBERT SIDNEY, Partner, Barnes-Pope Electric Co., Room 201 Sudbury Bldg., Boston, Mass.

REES, HARRY PEET, Instructor, The Engineering College of Brazil, Porto Alegre, Brazil.

ROBINSON, WALTER W. H. JR., Salesman, H. W. Johns-Manville Co., 100 William Street, New York City.

SAMPSON, HENRY LOUIS, Engineering Draughtsman, Board of Supervising Engineers, 181 La Salle St., Chicago, Ill.

SHEARER, CONWAY WING, Student, Columbia University; res., 71 East 82nd St., New York City.

SHEDD, HORACE EVERETT, Superintendent of Operation, Great Western Power Co., Oakland, Cal.

SHINN, WILLIAM C., 124 North 16th St., Lincoln, Neb.

SINSABAUGH, FRANCIS MARION, Manager Carrollton Heat, Light & Power Co., Carrollton, Illinois.

STEPHENS, FREDERICK STANLEY, Hyacinth Villa, 5, Elliot Lane, Calcutta, India.

STOCKBRIDGE, GEORGE HENRY, Assistant Supt. of Transmission, Southern California Edison Co., Los Angeles Cal.

STRUTHERS, HERBERT HARLOW, Electrical Engineer, Dow & Smith, 24 East 21st St.; res., 1 West 132nd St., New York City.

SWIGERT, WILLIAM EDWIN, Western Electric Co., New York City; res., 19 Martha Place, Passaic, N. J.

TAYLOR, JOSEPH BROWN, Vice-President W. S. Barstow & Company, 50 Pine Street, New York City.

THOMAS, FRANKLIN BAYARD, Superintendent of Power, The Smuggler Union Mining Co., Telluride, Colo.

TRAVER, OLIVER CLAGGETT, Assistant Electrician, New York and Honduras Rosario Mining Co., Honduras, C. A.

ULMER, MILTON, General Attorney and Engineer, Schondube & Neugebauer, Mexico City, Mexico.

VON BLUCHER, GEORGE ANTONIO, Tester, San Antonio Gas and Electric Company, San Antonio, Texas.

WAINWRIGHT, WALTER SCOTT KIMBALL, Assistant to Electrical Engineer, with Walter Kidde, 140 Cedar St., New York City.

WHITEHEAD, JAMES J., Assistant Engineer, Metropolitan Street Ry. Co., Room 209, 775 7th Ave., New York City.

WHITEHEAD, RICHARD HENRY, Supt., Ackerman Boland Telephone Co., Chicago, Ill.

WOLCOTT, KENNETH OLIVER, Western Electric Company; res., 150 West 98th St., New York City.

WORTHINGTON, CLAUDE GEORGE, Consulting Electrical En neer, 417 Loo Building, Vancouver, B. C.

WRIGHT, WILLIAM PERRY. Engineer and Electrician, Anderson, Cotton Mills, Anderson, S. C.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at a meeting held on February 11, 1910. Any objection to these transfers should be filed at once with the secretary.

CLIFFORD SHERRON MACCALLA, assistant to general manager, Washington Water Power Company, Spokane, Wash.

JOHN F. VAUGHAN, engineer, Stone and Webster Engineering Corporation, Boston, Mass.

WILBUR HAYES THOMPSON, sup't. and chief engineer, American Telegraphone Company, Wheeling, W. Va.

FRANK BALDWIN JEWETT, Transmission and Protection Engineer, American Tel. and Tel. Company, New York City.

Institute Meeting, February 11, 1910

The two hundred and forty-third meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Friday, February 11, 1910. The meeting was held under the auspices of the Telegraphy and Telephony Committee, and in accordance with previous custom at meetings held under the direct auspices of committees, Mr. William Maver, Jr., chairman of the committee, was called upon to preside. In the absence of President Stillwell, Secretary Ralph W. Pope called the meeting to order at 8:15 p. m. Mr. Pope announced that at the meeting of the Institute Board of Directors held during the afternoon 75 Associates were elected, and three Associates were transferred to the grade of Member. Chairman Maver then introduced Mr. W. Lee Campbell, of the Automatic Electric Company, Chicago, Ill., who presented a paper entitled " A Modern Automatic Telephone Apparatus." An interesting feature in connection with the paper was an exhibit of the Strowger automatic telephone exchange system with nine subscribers' stations which had been installed for the meeting in various parts of the auditorium. Mr. Campbell described the apparatus, and gave a number of interesting demonstrations of the operation of the system. The paper was discussed by Messrs. Ralph W. Pope, William Maver, Jr., Edward A. Mellinger, H. W. Pope, Charles A. LeQuesne, Jr., Parker H. Kemble, J. H. Shearer, and W. Lee Campbell and others.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before March 25th, 1910.

9227 Benner, E. H., Boston, Mass.
9228 Heald, H. W., Providence, R. I.
9229 Frazier, C. E., Wheeling, W. Va.
9230 Hooper, B. E., Placerville, Cal.
9231 McIver, Alexander, N. Y. City.
9232 Barringer, O. L., Charlotte, N. C.
9233 Carlson, E. E., Gary, Ind.
9234 Elden, H. F., Boston, Mass.
9235 Fox, J. W., Charlotte, N. C.
9236 Greeson, E. M., E. Pittsburgh, Pa.
9237 Hale, J. W., State College, Pa.
9238 Harding, R. M., Pensacola, Fla.
9239 Heyer, G. K., New York City.
9240 Lewis, F. P., Brooklyn, N. Y.
9241 Lipscomb, G. J., Iquique, Chile.
9242 Mambert, S.B., Brown Station, N.Y
9243 Matthews, H.D., Schenectady, N.Y.
9244 McLellan, R. L., Indianapolis, Ind.
9245 Molinard W. R., Cobalt, Ont.
9246 Sigg, J. J., Salem, N. C.
9247 Boor, E. B., Schenectady, N. Y.
9248 Gill, J. R., Boston, Mass.
9249 Hazra, L. F., Madison, Wis.
9250 Kartak F A., Madison, Wis.
9251 McManus, J. A., West Lynn, Mass.
9252 Oliver, F. P., Atlanta, Ga.
9253 Rittenhouse, L.H., Haverford, Pa.
9254 Smallhouse, A. B., Salt Lake City.
9255 Whiston, W. C., New York City.
9256 Wildin, G. W., New Haven, Conn.
9257 Bowman, D., Chicago, Ill.
9258 French, Burton, New Orleans, La.
9259 Heim, H. R., Minneapolis, Minn.
9260 Montgomery, J., Mexico City, Mex.
9261 O'Connell, J. H., Victoria, Aus.
9262 Real, Paul M., New Haven, Conn.
9263 Seaver, C. H., Chicago, Ill.
9264 Thomas, G. N., Toronto, Ont.
9265 Zimmer, L. P., Bath, N. Y.
9266 Aber, G. L., Bath, N. Y.
9267 Blackburn, L. A., Charlotte, N. C.
9268 Clarke, James, Jr. Louisville, Ky.
9269 Filkins, E. L., Milwaukee, Wis.
9270 Fries, H. E., Winston-Salem, N. C.
9271 Gauthier, G.J., Oklahoma City, Okla
9272 Kiley, W. R., Covington, Va.
9273 Narayan, S., Kashmir, India.
9274 Timbie, W. H., Brooklyn, N. Y.
9275 Warren, J. S., St. Louis, Mo.
9276 Denis, L. G., Ottawa, Canada.
9277 Hancock, J. W., Roanoke, Va.
9278 Hill, B. V., Chicago, Ill.
9279 Hiraiwa, T., Schenectady, N. Y.
9280 Hulett, F. M., Webb City, Mo.
9281 Ireland, L. G., Toronto, Ont.
9282 Massey, B. H., Charlotte, N. C.,
9283 Nick, E. W., Gatun, C. Z.
9284 Pierce, H. J., Minneapolis, Minn.
9285 Seeber, R. R., Winona, Mich.
9286 Bussey, H. E., Atlanta, Ga.
9287 Emery, H. H., Garden City, Kan.
9288 Geary, T. J., Jr. San Francisco, Cal.
9289 Horne, G. H., Pittsburgh, Pa.
9290 Kleffel, H. E., Charlotte, N. C.
9291 Klenk, F. F., New York City.
9292 Pyle, J. C., Los Angeles, Cal.
9293 Saunders, H. D., Newark, N. J.
9294 Schnyder, C. C. W., Chicago, Ill.
9295 Jones, R., Ithaca, N. Y.
9296 Mainwaring, W. H., Wilkes-Barre, Pa.
9297 Murphy, J. J., Rock Island, Ill.
9298 Marron, J. T., Rock Island, Ill.
9299 Elder, L. R., Portland, Ore.
9300 Wilson, J. S., Norwood, Ohio.
9301 Momota, S., Tokio, Japan.
9302 Birch, A. L., New York City.
9303 Eastman, M. L., Chicago, Ill.
9304 Herbert, C. D., San Francisco, Cal.
9305 Terrell, C. F., Seattle, Wash.
9306 Slimp, J. E., New York City.
9307 Waters, Harold, New York City.
9308 Wood, L. D., Brockton, Mass.
9309 Burnes, P. A., Poughkeepsie, N.Y.
9310 Fair, C., Schenectady, N. Y.
9311 Pace, E. J., Salem, Ohio.
9312 Patton, W. R., San Francisco, Cal.
9313 Scherling, G. J., Albany, N. Y.
9314 Stephens, P. V., New York City.
9315 Downer, J. M., Schenectady, N. Y.
9316 Harte, C. R., New Haven, Conn.
9317 Hodgson, O., New York City.
9318 Noerager, A. J., Rancagua, Chile.
9319 Strong, W. B., Washington, D. C.
9320 Tarkington, C. G., Pittsburgh Pa.

9321 Townsley, A.W., West Lynn, Mass
9322 Yost, V. A., Ossining, N. Y.
9323 Burke, D. W., Butte, Mont.
9324 Cooper, W. R., Indianapolis, Ind.
9325 Gardiner, J. H., Boston, Mass.
9326 Garland, N. M., New York City.
9327 Merwin, L. T., Goldfield, Nevada,
9328 Plumer, E. A., New York City.
9329 Rogers, F. A., Brockton, Mass.
9330 Scott, W. G., Montreal, Quebec.
9331 Shain, D. C., New York City.
9332 Sloan, J. S., Wilkinsburg, Pa.
9333 Triplett, R. L., Bluffton, Ohio.
9334 Woodward, C. V., Philadelphia, Pa
9335 Gray, J. E., Providence, R. I.
9336 Lefferts, E. B., Schenectady, N.Y.
9337 Wilson, H. T., Belvidere, Ill.
9338 Glodell, L. M., New Haven, Conn.
9339 Scott, Carl F., Yonkers, N. Y.
9340 Thornton, F., Jr., E.Pittsburgh,Pa.
9341 Wood, A. C., Philadelphia, Pa.
9342 Broughall, H. T., Brandon, Man.
9343 Dresser,R.E., Salt Lake City,Utah.
9344 Phipps, W. R., Galveston, Texas.
9345 Poats, T. G., Clemson College, S.C.
9346 Whitaker, J. H., Seattle, Wash.
9347 Zientz, L., New York City.
9348 Sutton, H. C., Eugene, Ore.

Total, 122.

Sections and Branches

Agricultural and Mechanical College of Texas Branch

The Agricultural and Mechanical College of Texas Branch, which was authorized by the Institute Board of Directors on November 12, 1909, was formally organized at its first meeting, held on January 14, 1910. The following officers were elected: Chairman, V. H. Braunig; secretary, R. T. Shiels. It was decided to hold monthly meetings, and a committee was appointed to arrange for programs for future meetings. The membership of the Branch consists of four Associates and 27 enrolled Students.

University of Arkansas Branch

The University of Arkansas Branch held its regular meeting in the engineering hall of the university on February 3, 1910. Professor W. N. Gladson, head of the department of electrical engineering, read a paper on "The Conservation of the Water Powers in Arkansas." Professor Gladson emphasized the importance of developing the water powers of Arkansas, on account of its limited supply of fuel, and the low percentage of heat obtained from it with the inefficient machinery available. The ease with which power can be transmitted, and the high efficiency of electrical machinery, renders the development of the state's water powers a promising field for engineers. Professor Gladson has been employed by the government to make a hydrographic survey of the streams of Arkansas. He described the method of measuring the power to be obtained from streams by means of a current meter, and he also exhibited lantern views of the stations and crews at work on White River.

Mr. W. G. Rye reviewed Professor W. S. Franklin's paper on "Space Economy of the Single-phase Series Motor."

Five-minute talks were given by Messrs. L. R. Cole and H. V. Crawford, on "Current News and Notes" and "Recent Installations."

The program concluded with a review of the events of the week by a talking arc, which also gave a violin solo.

Atlanta Section

The Institute meeting at Charlotte, N. C. on March 30, 31 and April 1, 1910, was the subject of discussion at the meeting of the Atlanta Section held on January 13, 1910. It was agreed that every effort would be made to insure the attendance of a strong delegation from the Atlanta Section at the Charlotte meeting.

Baltimore Section

The January meeting of the Baltimore Section was held on Friday evening, January 14, 1910, in the physics laboratory of the Johns Hopkins University. Mr. C. E. Allen, of the West-

inghouse Electric and Manufacturing Company, read a paper on "Transformers and Voltage Regulators." The paper was illustrated with lantern slides.

Boston Section

A special meeting of the Boston Section was held on January 8, 1910, at Tuft's College. At four o'clock the members gathered at Robinson Hall, where guides showed them through the laboratories. At 6:30 p. m. an informal luncheon was served, at which 40 persons were present. At 8:00 p. m. Dr. William L. Hooper, in charge of the electrical engineering department at the college, gave a talk on "The Necaxa Development of the Mexican Light and Power Company," which was illustrated by lantern slides. About 50 persons were present at the meeting.

On January 21, 1910 a joint meeting and dinner was held by the Boston Section, the American Society of Mechanical Engineers, and the Boston Society of Civil Engineers. A more extended report of this meeting appears elsewhere in this issue of the Proceedings.

Case School of Applied Science Branch

Twenty members of this Branch made a tour of inspection to Pittsburgh shortly before the holidays. Three days were spent in the plants of the Westinghouse Company and in the various steel mills in and around the city.

The next meeting was held on January 5, 1910, and the tour of inspection was discussed. Mr. F. L. A. Schmidt then gave an abstract of Dr. C. T. Hutchinson's paper on "The Electric System of the Great Northern Railway at Cascade Tunnel." Some of the features of the installation were discussed by Messrs. H. J. Hackenberg and S. G. Hibben.

Cleveland Section

The December meeting of the Cleveland Section was held in the Case School of Applied Science on December 20, 1909, with an attendance of 43 members, Mr. H. L. Wallau presiding. The subject of the meeting was "Electric Elevators," by Mr. Otis, of the Otis Elevator Company, and Mr. Houghton, of the Houghton Elevator Company, both of Toledo, O.

Mr. Louis B. Marks, consulting engineer, of New York City, was the guest of the Section at its meeting held on January 17, 1910. The general subject of discussion at this meeting was "Illumination," and was opened by Mr. Marks by an excellent address on "Lighting of Factories and Libraries," which was illustrated by a large number of lantern slides showing representative installations all over the country. Mr. W. W. Stephens, of the Welsbach Company, then took up the subject from the gas standpoint, in a paper entitled "Store Lighting," which was also illustrated by slides. The final paper was presented by Mr. J. G. Henniger, of the National Electric Lamp Association, on "Residence Lighting," and dealt with the subject from both the theoretical and practical sides. A warm discussion between the gas and electric men took place at the close of the meeting. There was a total attendance of 85 members and visitors.

University of Colorado Branch

Thirty-six members of this Branch met on December 15, 1909. Mr. D. A. Pickering described his experience with Westinghouse, Church, Kerr Company. Mr. F. Bliss gave a talk on the apprenticeship course of the General Electric Company, with which company he has been connected for the last two years.

On January 5, 1910, Mr. Earnest Prince presented a paper before the Branch, on "Electricity on the Farm." The paper brought out some interesting

facts in the application of electricity on the farm, especially that in connection with irrigation, where electric motors are used to pump water to irrigate large tracts of land. Mr. M. H. Putnam followed with a talk on "The Mercury Arc Rectifier."

Fort Wayne Section

The regular meeting of the Fort Wayne Section was held on Thursday evening, January 13, 1910, in the assembly room of the Fort Wayne Electric Works. Chairman E. A. Wagner presided, and introduced the speaker, Mr. Thomas W. Behan, who presented a paper on "Applications of Synchronous Converters and Motor Generator Sets." After a talk on the applications of these converter sets, Mr. Behan described three of the principal types on the market, these being the induction motor-generator type, the synchronous motor-generator type, and the synchronous converter, the last named being divided into two well known types; namely, the split-pole, and the booster. In considering the different types, Mr. Behan took up the subject of adaptation, cost of installation, and the results obtained from each. The paper was discussed by Messrs. L. D. Nordstrum, H. E. Crane, J. J. A. Snook and P. H. Hazelton.

Iowa State College Branch

The first meeting of this Branch for the spring term was held on February 2, 1910 in the engineering hall, with 20 members present. The principal business of the meeting was the election of officers. The following were elected: Chairman, Mr. Frank K. Shuff, succeeding Professor F. A. Fish; secretary, Mr. M. W. Pullen, succeeding Professor Adolph Shane; executive committee, Messrs. Fish, McElroy and Cover; social committee, Messrs. Mercer, Corlette and Chatterton. The rest of the evening was spent in planning for an electrical show. It was unanimously voted that no exhibits of an advertising nature would be permitted.

Ithaca Section

Mr. Percy H. Thomas, of New York, was the guest of the Ithaca Section at its meeting on January 21, 1910. Mr. Thomas presented a paper on "Lightning Protection." An abstract of the paper will be published in a future issue of the Proceedings.

University of Kansas Branch

The regular meeting of this Branch was held in Frazer Hall on January 19, 1910. Mr. F. P. Odgen presided. After the report of Messrs. H. A. Hoffman and G. V. Emery on current events in recent engineering publications, Mr. J. P. Hart was introduced, and spoke on "The Electrical Installation of a Modern Battleship." Mr. Hart is a graduate of the Naval Academy at Annapolis, and he spent several months on board ship. His description of the electrical appliances used on modern battleships proved very interesting.

Lehigh University Branch

The members of this Branch met in the physics laboratory of the university on Tuesday evening, January 18, 1910. The program consisted of two papers and a talk on the recent trip of the senior class to New York. The first paper was presented by Mr. J. S. Byerly, on "Magnetos." In his paper Mr. Byerly took up the subject of automobile magnetos in detail, and also described the advantages of this type of ignition for the high-pressure gas engine. Some attention was also given to high and low-tension magnetos. Mr. J. J. Sullivan read the second paper, entitled "Alternating Current Rectifiers," dealing with the various commercial forms of rectifiers. A detailed description was given of each. Mr. T. O. Beitzel then spoke of the annual trip of the senior class to New York, in which he pointed out to the members of the other classes the benefits to be derived from such a trip. The party spent several days in New

York, visiting the Waterside Station, the Interborough power plant, and numerous smaller plants, including that in the Singer Building. Several days were also spent at the General Electric Company's plant at Schenectady, after which the party returned to South Bethlehem. Refreshments were served at the close of the meeting.

Two papers were presented at the meeting of February 8, 1910; namely, "The Transformation of Electrical Energy into Light," by Mr. G. F. Bannson, and "Storage Batteries," by Mr. E. A. Warner. Mr. Bannson discussed the incandescence of various refractory substances, and the radiation effect with reference to spectrum lines and to temperature. Mr. Warner's paper dealt with the construction and applications of the storage battery. The different methods of charging and discharging the batteries were explained and also the different methods employed in connection with installation.

Madison Section

The regular meeting of the Madison Section was held in the auditorium of the engineering building, University of Wisconsin, on January 31, 1910, with an attendance of 45. Before announcing the program of the evening Mr. M. H. Collbohm, the presiding officer, expressed the appreciation of the members of the Section of the work done by the former secretary, Professor J. W. Shuster, during his four year term of office. The program consisted of a talk by Professor D. W. Mead on "The Selection of Machinery for Hydroelectric Plants." In his introductory remarks Professor Mead said that it is to be regretted that the selection of machinery is too often a matter of judgment based on previous experience, rather than the result of careful calculations based on a detailed consideration of the amount and varying demand of the power to be delivered. This is especially true of hydroelectric machinery, and because of the limited range of efficient operation of many water wheels now in use, the choice of machinery for hydroelectric plants is perhaps the most difficult of all. Professor Mead then discussed in detail the factors which enter into the choice of machines for hydroelectric use, illustrating his remarks by curves and diagrams projected on the screen from lantern slides. Different forms of load curves were discussed, and also the dependence of the design on the load curves, either actual or estimated. Curves of the efficiencies of various types of water wheels were shown as guaranteed by the manufacturers for specific cases, and other curves showing the actual efficiencies as calculated from the Holyoke tests of the same wheels. In most cases the best efficiencies were reached only under overload conditions; in some cases the guaranteed efficiency was considerably higher than the test showed could be obtained. This illustrates the policy of many water wheel manufacturers to furnish wheels too large for the work under consideration. This is because the wheel is selected by the manufacturer and sold under his guarantee to carry the load required. The wheel is then installed, rarely tested, and if it carries the load, nothing more is said. And in many cases, because the wheel is too large, it is operating at a very low efficiency, with a resulting loss of thousands of dollars annually to the owners of the plants so equipped. Because of the fact that the efficiency curve of the generator driven by the water wheel is nearly flat for a considerable range of load, and the range of efficient operation of the water wheel is more limited, it is easily seen that the efficiency of the units depends to a much larger extent upon the turbine than upon the generator. Therefore it is not only desirable but essential to base the selection of water wheels on a detailed analysis of the actual test of homologous wheels, and to select only such wheels as have been carefully tested and have shown

by such tests that they are suitable in size and characteristics for the work to be done.

Montana State College Branch

This Branch held its regular meeting on January 19, 1910. Mr. A. S. Brown gave a lecture on "High Frequency Currents." In the course of the lecture Mr. Brown reviewed the life and inventions of Nikola Tesla. He also discussed the development of the high frequency oscillator, and the applications of high frequency currents. Previously to the lecture a business meeting was held at which a committee was appointed to arrange for an electrical show to be given during April or May. This will be the third electrical show given by the Branch. Thirty members and guests attended the meeting.

University of Nebraska Branch

The third meeting of the University of Nebraska Branch was held on Tuesday evening, January 18, 1910. Professor G. H. Morse presided, and introduced the speaker, Mr. Edwin F. Schurig, of Omaha, who spoke on "Electrical Engineering Contracting." The various steps in the analysis of specifications, the preparation of an estimate, and the requisites of a proposal in engineering contracting, were explained thoroughly. There were 27 members present.

New Hampshire College Branch

The New Hampshire College Branch held a meeting on January 19, 1910, at which Professor C. E. Hewitt reviewed Mr. Henry L. Doherty's paper on "Development and Operation of Hydroelectric Plants." Professor Hewitt also related some of his own experiences in hydroelectric development, which he illustrated by views taken in the course of his travels.

Ohio State University Branch

The January meeting of the Ohio State University Branch was held in the electrical engineering lecture room on January 20, 1910. Committees were appointed to prepare for the electrical show to be given in March. Mr. J. E. Shepardson gave a talk on "Westinghouse Methods of Testing."

At the meeting held on February 7, Mr. S. E. Gillespie gave a talk on "Automatic Interlocking Systems." The committee in charge of the program for the coming electrical show reported its progress. It was voted to invite the mechanical engineering department to co-operate with the electrical engineers in the show.

Oregon Agricultural College Branch

At the November meeting of this Branch it was decided to have a series of papers on electrochemistry. The first of these papers was presented at the meeting of the Branch held on December 20, 1909. It was in the form of an introduction of the subject, and was presented by Dr. W. Weniger. This was followed by a review of Mr. H. L. Doherty's paper on "Development and Operation of Hydroelectric Plants," by Mr. E. V. Hawley.

The second paper on electrochemistry was presented at the meeting held on January 31, 1910, by Messrs. Plankington and Powell, the subject being "Batteries." The various types of primary and secondary cells were discussed. Special emphasis was laid on the commercial uses of storage batteries. Mr. E. R. Shepard gave a talk on "Thermite," in which he brought out many interesting facts regarding the production of aluminum. Both papers were accompanied by experimental demonstrations.

Pittsfield Section

The manufacture of iron and steel by the application of the principles of electricity to metallurgical processes was the subject of discussion at the meeting of the Pittsfield Section held in

the Wendell Hotel on February 3, 1910. Dr. Joseph W. Richards, of Lehigh University, past-president and present secretary of the Electrochemical Society was the principal speaker. An abstract of Dr. Richards' lecture is printed elsewhere in this issue.

Portland Section

The meeting of the Portland Section on January 18, 1910, was devoted to industrial power subjects. The following papers were read and discussed: "Irrigation," by Mr. F. F. Barbour; "Individual and Group Driven Machine Tools," by Mr. C. C. Crawford; "The Uses of Electric Motors in Saw Mills," by Mr. L. Quimby; "Electric Hoisting in the Butte Camp," by Mr. C. B. Smith; "Electric Furnaces," by Mr. E. A. West. The meeting was prolonged to a late hour, and several papers that had been arranged for were held over. The discussion of the papers evoked such interest that it was decided to devote the February meeting to industrial power subjects.

Purdue University Branch

On November 9, 1909, the members of the Purdue University Branch were addressed by Mr. G. T. Dunklin, on "Determination of Practical Formulas for Sheet Steel Enamels." While the subject of enameled steels has no direct connection with electrical science, yet steels so enameled are used to such an extent in certain types of electric lighting apparatus that the discussion may be of interest to many electrical engineers. Mr. Dunklin has spent much time in careful research work. He spoke of the methods he had pursued in determining the exact formulas for these enamels. A summary of his remarks is as follows:

Enamel is made from glass and a number of chemicals which are fused in a furnace, cooled in cold water and ground while wet in mills. It is then applied to the steel surface by simply dipping the metal in the enamel, which somewhat resembles paint. Then it is baked in an oven until the enamel fuses with the steel surface. Usually three coats are applied in the same manner, although the coats are chemically made up somewhat differently.

In the attempt to get the basis of enamel chemistry, scientific periodicals were resorted to by Mr. Dunklin but all that could be obtained from this source were the usual ingredients used in making the enamel. From the dealers in the raw materials for enamels, valuable information was gained, and finally, through an ingenious method requiring patience and a knowledge of chemistry, the formulas giving the best enamels were worked out. The ingredients being known, it remained to determine their proportions. The only method of ascertaining this was by the simple "cut and try" method. Of the six oxides known to be used, one was varied in amount, while all the rest remained constant. Nine different tests of variations were made with each metal. Then the test giving an enamel approaching nearest the one sought, was made the basis for the next series of tests. This means that the enamel sought was obtained, since by each series of tests ingredients in the proper proportion were determined by selecting the most perfect enamel each time. The compounds upon which the determinations were based are the oxides of silicon, aluminum, barium, potassium, sodium and calcium. Since these oxides are obtained from complex compounds, the amounts used in the determinations do not represent the weights of the materials to be used, for the equivalent weights of the particular chemicals used in the mixture must be considered, and not the weight of the entire compound from which the oxide is derived. This was another problem requiring thought and ingenuity to solve. From the atomic weights of the elements and the formulas of the compounds, the batch weights of the different ingredients were obtained in proportions to satisfy those worked out.

At the meeting held on November 23, 1909, Mr. C. R. Moore spoke on the subject of "Electrical Chronometers," speaking from his personal experience in the building of five different models, one of which was exhibited to the members of the Branch. This clock was constructed on the principle that the spring which makes the battery contact should also be made to give the impetus to the pendulum, which was very massive and made to beat seconds. The clock was very carefully constructed and has been quite successful. On one month's trial it kept accurate time. The apparatus involved is simple and adjustments are very easy. Then, too, it has the essential feature that it is independent of battery strength, and difference of strength in the batteries has no effect whatever on the time-keeping qualities of the clock. He explained how the clock might be made to operate as a master clock and give standard time to several clocks located in different places. He also explained the value of a central clock in factory use, and how it could be used as a master clock and keep time in all departments of the factory. Besides discussing his own model Mr. Moore explained fully, facts regarding various other electrically controlled time-keeping apparatus and their relation to modern shop practice.

The meeting of December 14, 1909, was devoted to a discussion of Dr. C. T. Hutchinson's paper "The Electric System of the Great Northern Railway Company at Cascade Tunnel." The principal speakers were Professor H. T. Plumb and Mr. J. A. Diener, and several important points were brought out in the discussion. Professor Plumb has visited the locality of the tunnel, and told of the conditions before the electric system was installed. Mr. C. C. Beck explained the design of overhead wires, insulators and fixtures used on this installation.

Captain Benjamin Watkins, U. S. A., detailed at Purdue University, addressed the members of the Branch on January 18, 1910, on the subject "Signaling in the U. S. Army."

Bombs, flags, heliograph, mirrors, acetylene lamps, searchlights and electrical instruments are used for signaling by the United States Army. The telephone, telegraph, wireless telegraphy and the buzzer are also used. Of these the buzzer is the most serviceable. The field telephone is very compact, being somewhat similar to the test set used by trouble hunters in telephone work, and is made specially for the United States Army. Its use is restricted to camps and the more permanent army posts. The line is built on lances, and is of the single wire type. Telephones are used principally in coast artillery work. The Morse relay in use in the army is similar to the commercial instrument, and its use is restricted to permanent lines. The wireless telephone is very rarely used, the principal objection being its weight. The weight of a wireless telegraph outfit as now used is less than 200 lb. and the outfit is very compact. The buzzer is the most reliable of all signaling instruments. It can be depended upon to work under almost impossible conditions, such as over a broken line; a line constructed through a stream, or over wet ground or an uninsulated line. Its weight is less than 12 lb., while the cavalry buzzer weighs only five lb. Captain Watkins cited an instance where the buzzer has sent messages over a break in the line 30 feet long. The line consists of a single wire with ground return, the ground usually being through the operator's body. Messages are sent at the rate of 20 words per minute. The sending apparatus consists of a push button, induction coil, vibrator, and five dry batteries. When the transmission is good, a microphone is used with the cavalry buzzer in place of the vibrator. A telephone receiver is used for receiving messages, with the Morse code. Each

cavalry division carries 72 miles of iron wire weighing 100 lb. per mile, and 70 miles of insulated copper wire weighing 77 lb. per mile. Lance lines are used for permanent work, the lances being about 3 in. in diameter and 10 ft. long. The construction of a three-mile line is an hour's work for 50 men; five miles can, in case of necessity, be built in the same time.

San Francisco Section

The San Francisco Section held its regular meeting on January 28, 1910. In the absence of the speaker for the evening, Mr. W. J. Davis, Jr., who unfortunately was called away, Messrs. Shreve, Vickers and Dunn volunteered three short papers on the subject of "The Low Pressure Steam Turbine." Messrs. Shreve and Vickers explained in detail the General Electric low pressure steam turbine, and Mr. Dunn described the Westinghouse low pressure steam turbine. The papers were well illustrated with working drawings and detail parts of all classes of low pressure turbines. Perhaps the most interesting part of the papers was the charts and curves showing the high economy effected by the low pressure turbine, particularly when used in plants where economy was not of the best.

One hundred and fourteen members were present. The usual informal dinner preceded the meeting.

Schenectady Section

On January 18, 1910, the Schenectady Section gave a very successful "smoker," at which about 350 members were present. The entertainment consisted of vaudeville acts, character sketches, victrola records, stereopticon views, and selections by the Edison Club orchestra of 20 pieces. The entertainment committee also provided refreshments.

Mr. Charles Fair, who has been actively connected for several years with the development of motor-driven machine tools, was the speaker at the seventh meeting of the Section on February 1, 1910. About 200 Institute members were present. Mr. W. L. Merrill, representing Mr. D. B. Rushmore, chairman of the Institute Committee on Industrial Power, presided.

Mr. Fair first took up the advantages of electrically driven tools. He spoke of the sanitary improvements, the effect on the operators, and the increased output. He also mentioned several accepted methods of applying motor drive to machine tools, and of applying electrical control to machines which originally were belt-driven. At this point Mr. Fair brought out many interesting reasons for the changes which would not be apparent to the casual observer. He next took up the application of motors to machine tools where the machines were built as complete units, and explained the difficulties experienced in bringing the control to convenient points. He then showed a number of lantern slides illustrating how some of these difficulties had been surmounted. An interesting illustration was that of a huge planer requiring an aggregate of 250 h. p. in various motors used to operate different parts of the machine. The photograph showed 87 men standing on the machine, bringing its total weight up to 800,000 lb. Numerous other photographs were also displayed, illustrating some of the adverse conditions under which machine tools are being operated in some shops, and the roundabout methods used in supplying power.

At the close of Mr. Fair's paper Mr. A. L. Rohrer opened a general discussion of the subject. Mr. Rohrer stated that there are at present over 8,000 motor-driven machine tools at Schenectady, with an aggregate of 19,000 h. p. Many points of interest were brought out in the discussion.

Seattle Section

Fifty-five members of the Seattle Section met at Science Hall, of the University of Washington, on January 15, 1910. Mr. A. A. Miller, who has since

succeeded Mr. J. H. Harisberger as chairman of the Section, presented a paper on "Single-Phase Railway Equipment." Mr. Miller predicted the increasing popularity and use of the single-phase system for railway purposes both at home and abroad. He gave valuable data regarding installation, operation and maintenance costs. He stated that the average cost per car mile of the single-phase system is considerably less than that of the direct current. The paper was amply illustrated with stereopticon slides showing motors and installations in various sections of the country. Mr. A. S. Moody then spoke of the merits and advantages of the 1200-volt direct-current system for railway electrification. A general discussion of both systems followed, in which Messrs. Harisberger, Dodds, Brown, Moody and Miller took part. After the reading of the papers and the discussion, the election of officers for 1910 took place. Mr. A. A. Miller was elected chairman, and Mr. W. S. Hoskins was elected secretary-treasurer. Professor Magnusson spoke briefly in commendation of the excellent work of the retiring officers, after which the meeting was adjourned.

University of Texas Branch

The first meeting of the University of Texas Branch for the year 1910 was held on January 14, 1910, in the engineering building, with 10 members present. The program consisted of a paper on "The Talking Arc and its Relation to Wireless Telephony," by Dr. A. C. Scott. The paper was illustrated by a talking arc in actual operation, and the theory of its operation was explained by Dr. Scott.

Another meeting took place on January 28, and the following papers were read: "Possible Water Powers to be Developed in Texas," by G. M. Thomas; "Devices for Synchronizing Alternating-Current Apparatus," by T. A. Hard, Jr.; "Measurement of Temperature by Electrical Means," by G. H. Brush.

Toledo Section

The Toledo Section had as a guest at its meeting on January 7, 1910, Mr. C. E. Delafield, of Ampere, N. J. Mr. Delafield gave a short talk on Institute work and the conduct of meetings. He also spoke briefly of some of the difficult problems arising in the application of electric motors requiring special operating conditions. An instance cited was a series of motors operating a machine for the manufacture of wood pulp. The requirement in this case was that the motors must have a definite speed relation to each other, and be varied synchronously over a range from one to four and one to ten.

At the meeting of February 4 the members of the Executive Committee were elected as follows: M. W. Hansen, chairman; John Gilmartin, vice-chairman and chairman of the program committee; George E. Kirk, secretary; C. B. Nichols, chairman of the membership committee, and Emil Grah. The papers presented were: "Theatrical Wiring," by Mr. F. L. Lucas, assistant city inspector, and the "Electrical Code," by Mr. C. D. McCall, city inspector. Mr. Lucas discussed theatrical wiring in general, and exhibited samples of switches and cables. Mr. McCall stated the causes leading up to the adoption of the electrical code and electrical inspection in Toledo, and the methods adopted to insure safety in electrical installation.

Toronto Section

The Toronto Section held its January meeting on Friday, January 21, at the Engineers' Club, Toronto. About 40 members met at the St. Charles Cafe for luncheon. The meeting was called to order at 8:30 p. m. by Mr. H. W. Price, chairman, who introduced Mr. P. M. Lincoln, of Pittsburgh, chairman of the Institute Sec-

tions Committee. Mr. Lincoln presented a paper on "Some Recent Developments in Electrical Engineering." He stated his inability to cover the entire field owing to the advances in electrical engineering during the last few years, and that he would therefore touch only on the more important work. Speaking of the developments in high-tension transmission, he pointed out two notable advances, both in connection with the problem of insulation; namely, the adoption of the suspension type of line insulator, and the development and use of the condenser type of high-tension bushing. After a summary of the general developments in insulators, Mr. Lincoln concluded that with the new type of suspension insulator, limitations from line insulation were removed to the terminal apparatus, inasmuch as by using a sufficient number of overhung insulator sections in series, the insulation on the line can now be carried to any desired extent. In the problem of taking care of the insulation of this terminal apparatus, the second improvement plays an important part.

The terminal apparatus on transmission lines consists essentially of transformers and switches; there are some other types of apparatus which have to be used, but the two before mentioned are peculiar in that they both have to make use of oil. Now, when oil is used in electrical apparatus it is highly desirable to confine it in strong metallic steel tanks, as containers for the oil are universally used. It is practically impossible to insulate these steel tanks, and therefore we at once have the problem of insulating the tanks from the high-tension conductors which must pass into and out of them. This is admirably performed by the so-called condenser type of bushing. This type of bushing enables us to insulate a steel tank from a high-tension conductor by a solid mass of insulation, and the voltage strains throughout this solid mass of insulation are so distributed by the condenser that no voltage strains across one lamina of insulation are materially greater than those across any other lamina. The bushing has already demonstrated its tremendous value in many cases, and its use has removed one of the limitations of high-tension apparatus which for a time threatened to limit the further increase of high-tension transmission voltages. Continuing, Mr. Lincoln discussed the use of steel towers, and the adoption of the electrolytic lightning arrester, which cover the more important advances in high-tension transmission.

After speaking briefly of some of the other branches of electrical engineering, Mr. Lincoln discussed at some length the increasing use of the synchronous condenser for power-factor correction, citing numerous cases to illustrate the applications of the synchronous condenser. He then spoke on the relationship between the engineers in the various branches of the profession. The reading of the paper was followed by a lengthy discussion, in which the following gentlemen participated: R. G. Black, K. L. Aitken, A. L. Mudge, H. U. Hart, C. A. Price, A. S. L. Peaslee, Harold Brown, Professor Rosebrugh, A. J. Soper. At the request of the chairman Mr. Lincoln gave the members a resume of his recent trip to the Pacific coast, after which the meeting was adjourned.

Washington Section

The December meeting of the Washington Section was postponed. The January meeting was held in the George Washington University on January 11, 1910. Forty-seven members were present. A paper was presented by Mr. C. H. Scott, entitled, "New Developments and Applications of Electric Motors with Notes Relative to Motor Manufacturing Processes and Testing Methods."

Worcester Polytechnic Institute Branch

Mr. E. C. Morse, of Boston, Mass., addressed the members of the Wor-

cester Polytechnic Institute Branch at a meeting held on January 28, 1910, on the subject, " Industrial Application of the Electric Motor." Seventy-five members and friends attended. Mr. Morse first gave a comparative account of the merits and deficiencies of the various types of motors for work in industrial application. For variable speed he thought the shunt motor and compound-wound motor the more desirable, while in damp places as in paper mills the induction motor is more suitable. The operating characteristics of these motors were shown by means of lantern slides. Taking up the application of these motors, Mr. Morse gave consideration to three typical industries in which this type of drive is finding extensive use; namely, woodworking machinery, machine tools, and paper mill machines. Lantern slides were shown of a number of woodworking rooms in which each machine had its separate motor easily controlled from a box at the side. For protection, wooden cases were used over the motor. In the matter of machine tools, slides showing lathes, planers, shapers, etc., were exhibited. Paper mill apparatus, beating engines, and other machinery were also shown with driving motors of rather large individual capacity. In the discussion at the conclusion of the paper, a number of facts in regard to the economics of the substitution of the motor-drive for belt-drive were brought out.

At the meeting of February 11, 1910, the Branch was addressed by members of the senior class, on various types of electric motors. Forty-five members and friends were present.

The first speaker, Mr. W. R. Bell, spoke of the direct-current shunt motor. Commencing with the principles of electromagnetism, Mr. Bell explained the fundamental operations of the motor, so that the reasons for the action of this machine with varying field, varying load etc., could easily be comprehended. Sketches and lantern slides aided the speaker in illustrating the subject.

Mr. W. C. Greenough took up the series direct-current motor. After a description of the points of difference between this motor and the shunt motor, Mr. Greenough took up the elementary calculations used in motor work, showing their application. The operating characteristics of the motor were explained, and the application of this type of motor was shown by a number of samples.

The single-phase commutating alternating-current motor was the subject of Mr. M. F. Clement's talk, who opened his remarks by a brief outline of the objections to the direct-current motor for railway work. An explanation of the essential parts of the alternating-current motor was followed by the consideration of the action of the interpole to preventing sparking at the commutator.

The last speaker was Mr. R. S. Gold, who discussed the induction motor in its various types. With the aid of lantern slides Mr. Gold showed the structural features of these motors, and by means of curves explained the operating conditions.

At the conclusion of the program, Professor Smith gave an explanation of a mechanical model recently constructed at the Worcester Polytechnic Institute by means of which the resistance and inductance of the electric current were demonstrated

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The Electric Fixation of Nitrogen*

BY M. W. FRANKLIN

One of the most pressing of modern problems is the supply of combined nitrogen for agricultural purposes. There are three substances essential to vegetable life which are constantly being extracted from the soil by the crops or plants growing thereon. These

* Abstract of an address by Dr. M. W. Franklin before the Pittsfield Section of the American Institute of Electrical Engineers on November 23, 1909.

are nitrogen, phosphorous and potassium. The continual abstraction of these substances renders necessary their periodic replacement if the soil is not to be impoverished. In early agricultural operations animal fertilizer sufficed for the needs of the time, but in recent years the supply has become inadequate, and it has become essential that some form of artificial fertilizer be employed. Nitrate of soda and sulphate of ammonia have been extensively used for this purpose with very satisfactory results. The increased demand for these drugs, however, has limited the supply. It is estimated that the consumption of Chili saltpetre has increased in the period from 1850 to 1903 from 250,000 tons to 1,540,000 tons annually, and at the present time the rate of consumption is in the neighborhood of 2,000,000 tons per year. For many years Peruvian guano has been used, but the supply is practically exhausted. The sewage from cities if utilized in an efficient manner would prove at best but an insignificant item in the total world's demand. It has been estimated that in England alone there is wasted through her sewers the equivalent of $80,000,000 per year. No efficient method has as yet been proposed for the satisfactory utilization of city sewage. Sulphate of ammonia is now manufactured in large quantities as a by-product in gas works. It is improbable, however, that this form of combined nitrogen can successfully replace Chili saltpetre when the latter shall have become exhausted. Nitrogenous compounds are unstable chemically, and this instability has rendered the fixation of nitrogen difficult by artificial means, a critical temperature of dissociation existing so near the temperature of combination that disintegration is prone to occur immediately after the combination has been brought about. There are two proved methods for fixation—the Birkland-Eyde process, and the cyanamide process of Caro and Frank. A modification of the Birkland-Eyde process due to Dr. Schonherr and operated by the Badische Aniline und Soda Fabrik is worthy of description. The principle upon which all these processes is based, is the treatment of air to a high temperature while passing through a strong electrostatic field. Under this influence the nitrogen of the air combines with oxygen, but decomposes practically as soon as the combination occurs. This decomposition has been prevented by removing the high temperature in the static field as soon as the combination of nitrogen and oxygen has been obtained, or, in other words, the air is subjected to a rapid periodic treatment. In the Birkland-Eyde process a high-tension alternating-current flame is blown into a disc transversely to a direct current magnetic field. The gases mixed with steam are passed directly over lime. This process is modified in the Badische Aniline und Soda Fabrik. In the latter, long thread-like arcs are employed. The air is blown tangentially so as to circulate spirally around the arc. The difficulties encountered in the development of these pro cessesin the past, have been the high cost of electric power and the fact that the process of nitrogen fixation in the flame is a reversible one. At certain critical points the combined nitrogen is again decomposed and it is with the perfection of this detail that the development has been concerned, cheap water power having been available in many places for some time.

Electrometallurgy of Steel and Iron*

BY JOSEPH W. RICHARDS

The most modern of industries, electrometallurgy, has for its purpose the application of electricity to metallurgical processes, with a view thereby of obtaining products not capable of being produced in any other way, and also of obtaining older products either more

* Abstract of an address by Dr. Joseph W. Richards before the Pittsfield Section of the American Institute of Electrical Engineers on February 3, 1910.

economically, or superior in quality. Electrometallurgy has demonstrated that it can do all of these things, and therefore there can be no doubt that it is destined to play a large part in the manufacture of such products in the future. This new industry combines the principles of electricity and chemistry, and engineers to be successful in this field must have training both in electrical engineering and metallurgy. Electricity is used in the processes of metallurgy in two ways. First, electrolytically, whereby electrolysis is used for the purpose of obtaining the desired results. In this method, direct currents are used, and the output of the processes is directly proportional to the current used. Electrolytic iron, which is the purest kind of iron, can be combined in this way at a cost of refining of $10.00 per ton. In the second method, the heating effect of the electric currents is used to obtain the high temperatures necessary for metallurgical operations. This can compete with the ordinary methods notwithstanding the cost of electric power, owing to the fact that heat can so easily be applied just where it has to be used, thus resulting in economical use of power and high efficiency. Furnaces in which the current is utilized for its electrolytic action and heating effect are called electrolytical furnaces. They may use either direct or alternating current, and the output is directly proportional to the watts input, the efficiency being the proportion of the heat utilized in the metallurgical processes to the heat generated in the furnace. Electric furnaces are of two types—arc furnaces, and resistance furnaces. In arc furnaces, the substance dealt with may constitute one or both poles of the arc. It may be placed in the path of the arc between the poles, or it may be placed entirely outside, and heated by radiation from the arc. In resistance furnaces, the substance to be heated constitutes the resistance through which the current is passed; the simplest type of this consisting of a long, narrow, serpentine channel containing the material to be melted. Terminals are placed at each end, and sufficient voltage applied to force the required current through the material. In the induction type of furnace the resistance, which constitutes the material to be melted, is made the secondary of the transformer in which the heating current is induced from the primary coil. The resistance in this case is placed in an annular channel surrounding an iron core, making thereby a one-turn secondary coil. The primary coil is wound directly on the core inside the annular secondary. The greatest difficulty of this furnace is to obtain successful screening of heat from the primary coil and core, for which purpose a water jacket is used. These induction furnaces are in successful operation up to 15 tons capacity, and one of 25 tons capacity is now in course of construction. The electrometallurgy of steel was first attempted in the manufacture of ferro alloys, which previously could not be made. These alloys required for their manufacture a temperature which can only be obtained by the electric furnace. The next step was the manufacture of the highest and most expensive grade of steel; that is, crucible steel. Electric furnaces can now be utilized to manufacture exactly the same quality of steel as crucible steel, in much larger quantities, of more uniform grade, and at about one-half the former cost. There is no doubt that the old method of manufacturing crucible steel is destined to be entirely replaced by electrical methods. Where electric power is available in large quantities at small cost, electric furnaces are beginning to compete in the manufacture of steel called electric steel, which is considerably better than open hearth steel. The difficulty in the past has been that the small furnaces used, had low efficiencies, but as larger furnaces are being built, the efficiencies are steadily increasing, and consequently reducing the cost. At present an efficiency of

80 per cent has been obtained. At some places this steel is now being manufactured at a cost only slightly in excess of the cost of open hearth steel, and it is reasonable to assume that the future will see a still further reduction in cost of manufacture.

Personal

MR. CHARLES J. GRAHAM, of the American Telephone and Telegraph Company, has been transferred from Troy, N. Y. to Boston, Mass.

MR. DAVID R. SHEARER has been appointed electrical engineer and draughtsman with the Tennessee Copper Company, Copperhill, Tenn.

MR. L. H. THULLEN, consulting engineer, of New York City, has accepted the appointment of chief engineer for the Triumph Electric Company, Cincinnati, Ohio.

MR. C. OTTO VON DANNENBERG was recently transferred from the construction department of J. G. White and Company at Indianapolis, to the company's New York office.

MR. CARLOS DEL RIO, formerly with the Mexican Light and Power Company, Mexico City, has resigned to engage in construction work. His address is Cardenas, Tabasco, Mexico.

Mr. J. McALLISTER STEVENSON, JR. has completed his work as consulting engineer for the Mountain Mill Paper Company, Lee, Mass., and is now located in Sweetwater, Texas.

MR. F. C. FINKLE, consulting engineer, announces the removal of his office from the I. W. Hellman Building, to 628½ South Spring Street, Los Angeles, Cal.

MR. G. E. ANDERSON has left the Automatic Electric Company, Chicago, Ill., and accepted a position with the Home Telephone Company, San Francisco, Cal.

MR. F. GANGYL has resigned his position with the Toledo Railway and Light Company, to become electrical engineer with The Northern Ohio Traction and Light Company, Akron, Ohio.

MR. A. GUERRA, formerly with the Westinghouse Electric and Manufacturing Company, at Pittsburgh, is now with the General Electric Company. His address is P. O. Box 926, Schenectady, N. Y.

MR. WILLIAM G. GETZ, electrical assistant, U. S. Signal Service, has left New York for Fort D. A. Russell, Wyoming, where he will superintend the construction of a post telephone system.

MR. F. V. SKELLEY has been transferred from the engineering department of the Western Electric Company, Hawthorne, Ill., to the general power apparatus sales department of the same company at 463 West Street, New York.

MR. JAMES A. WALTON has left the Consolidated Gas, Electric Light and Power Company, of Baltimore, and is now associated with the Edison Electric Illuminating Company, of Boston, Mass., in the electrical engineering department.

MR. CHARLES D. WESSELHOEFT, formerly with The Arnold Company, announces his connection with The Fuel Engineering Company, 1712 Marquette Building, Chicago, which conducts a general consulting engineering business.

MR. BION J. ARNOLD, consulting electrical engineer of Chicago, has been engaged by the committee on local transportation of the Chicago City Council, to prepare working plans for

an extensive system of subways in the Chicago business district.

MR. EDGAR FRANCIS BEAUBIEN has resigned his position with the patent department of the Western Electric Company in New York City, and is now with Mr. Charles Gilbert Hawley, Marquette Building, Chicago, Ill., in the capacity of patent soliciter.

MR. C. A. BERNIER, lately superintendent of the Winona Railway and Light Company, resigned on February 1, and is now connected with the Helena Light and Railway Company as superintendent of electric lighting.

MR. A. WESTMAN having resigned from the General Electric Company has joined the engineering staff of the electrical department of the New York, New Haven and Hartford Railroad Company. Mr. Westman's headquarters will be at New Haven.

MR. BAXTER REYNOLDS has taken up the sale of electrical machinery for the Burke Electric Company. In partnership with Mr. H. B. Coho, who has handled the line for some years, Mr. Reynolds will operate in New York and New England territory.

MR. F. E. MCKEE, who until February 1, was electrical engineer for the Pressed Steel Car Company, Pittsburgh, Pa., has severed his relations with that company to accept a position as assistant manager of The Shaw Electric Crane Company, Muskegon, Mich.

MR. J. C. ELBERSON, who formerly was chief engineer of the Philadelphia and Western Railway Company, recently resigned that position, and is now with The Electric Storage Battery Company, of Philadelphia, Pa., as engineer of the sales department.

MR. FRED B. CROSBY, after five years service with the General Electric Company, the last two years in the power and mining engineering department, has resigned and accepted a position as technical writer with the Westinghouse Electric and Manufacturing Company.

MR. FRANCIS J. WHITE, until recently engineer under Mr. George Gibbs, chief engineer of electrical traction and station construction, Pennsylvania Tunnel and Terminal Railway Company, has resigned to accept a position with The Okonite Company, 253 Broadway, New York.

MR. ROY W. BROWN, who for several years has been connected with the Globe Electric Manufacturing Company at Amsterdam, N. Y., is now associated with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., as engineer in the electric controller department.

MR. R. S. SHOEMAKER having severed his connection as electrical engineer with the Pittsburgh Steel Company at Monessen, Pa., accepted on December 15, 1909 the appointment of assistant consulting engineer with The Algoma Steel Company, Limited, Sault Ste. Marie, Ont.

DR. FREDERICK BEDELL, vice-chairman of the Ithaca Section, sailed with his family on January 29, 1910, for a trip abroad. After visiting Algiers and other Mediterranean countries he will proceed to France and Germany, returning to this country next September.

MR. R. L. WEBB having left the employ of Viele, Blackwell and Buck, New York City has formed a partnership with Mr. Thomas F. Cooke, and will conduct a general consulting, mechanical and electrical engineering business, making a specialty of industrial power plants and applications of power.

Mr. Lynne W. Eddy, who for two and a half years has been with the Western Electric Company, in the power apparatus department, has left that company to accept a position as assistant engineer in the district office of the Crocker-Wheeler Company, 675 Old Colony Building, Chicago, Ill.

Mr. Joseph Damond Whittemore, who until February 1 was with the construction department of the General Electric Company's Boston office, is now associated with the engineering department of the Rochester Railway and Light Company, where he is engaged in industrial engineering work.

Mr. H. A. Steen, formerly designing engineer of industrial controlling devices with the Westinghouse Electric and Manufacturing Company, with which company he has been connected for the last seven years, has accepted a similar position with the Allis-Chalmers Company, Milwaukee, Wis.

Mr. John C. Parker, mechanical and electrical engineer for the Rochester Railway and Light Company, Rochester N. Y., has been appointed non-resident lecturer in electric power transmission at the University of Michigan, Ann Arbor, Mich. He will deliver lectures every Saturday morning for the rest of the school year.

Mr. Emil Podlesak, who has been engaged in construction work at Morristown, N. J., has given it up to take the position of superintendent of experiments with the Webster Electric Company at Tiffin, Ohio. This company was organized to manufacture sparking magnetos under patents of Mr. Podlesak and his brother Henry J. Podlesak.

Mr. Parker H. Daggett has been appointed professor of electrical engineering in the University of North Carolina, Chapel Hill, N. C. Professor Daggett was formerly assistant in electrical engineering at Harvard University. For the last six months he has been in the engineering department of the American Telephone and Telegraph Company.

Mr. Karl B. Kumpe was appointed assistant engineer of the Oregon and Washington Railroad in May 1909, with offices in the Central Building, Seattle. The Oregon and Washington Railroad is the extension of the Harriman system from Portland, Ore., to the Puget Sound country. Mr. Kumpe was formerly with the Chicago, Milwaukee and Pudget Sound Railway.

Mr. P. D. Wagoner has been elected president of the General Vehicle Company, Long Island City, succeeding Mr. J. Howard Hanson, who has withdrawn from the company. Mr. Wagoner brings to his new work a wide experience in engineering and commercial affairs, and under his administration the outlook for the future of the General Vehicle Company appears very bright.

Mr. William L. Puffer, formerly associate professor of electrical engineering at the Massachusetts Institute of Technology, has opened offices in rooms 801-802, Boston Safe Deposit and Trust Company Building, 201 Devonshire Street, Boston, Mass., where he will conduct a consulting and expert electrical engineering business in all of its branches.

Mr. C. F. Elwell has obtained the rights in the Poulsen Wireless Telephone and Telegraph Company for the Poulsen system of wireless telephony and rapid wireless telegraphy. Mr. Elwell is president of the American company owning these rights in this country. It is planned to demonstrate the system and introduce it into commercial use sometime during the year.

Mr. Albert Spies retired on February 1 from the editorship of *The Electrical Record*, to become managing

director of *Foundry News*, a new illustrated monthly publication devoted to the foundry arts, with offices in the Hudson Terminal Building, 50 Church Street, New York. *Foundry News* will make its first appearance in April.

MR. EDWARD LYMAN WILDER, who until February 1 was associated with the Westinghouse Electric and Manufacturing Company, in the railway division, is now connected with the engineering department of the Rochester Railway and Light Company. Mr. Wilder will devote his attention to storage battery studies for station and vehicle service, and will make comparative investigations of various prominent types of storage batteries.

DR. EDWARD G. ACHESON, president of the International Acheson Graphite Company, Niagara Falls, N. Y., was awarded the Perkin Medal on December 13, 1909, by the unanimous vote of the Society of Chemical Industries, American Chemical Society, and the American Electrochemical Society. The presentation was made at the Chemical Club, New York City, on January 21, 1910. The Perkin Medal is a gold decoration awarded annually to the American chemist who has accomplished the most valuable work in applied electricity during his career.

Obituary

MR. JAMES WELDON BRIDGE was accidently shot and killed at Monongahela, Pa., on December 18, 1909. Mr. Bridge was born at Atlanta, Ga., on March 24, 1873. He was a graduate of the Georgia Institute of Technology, and for a number of years was general shop foreman of the Atlanta Railway and Power Company. Subsequently he became associated with the West Penn Railways Company as superintendent of rolling stock and equipment, which position he held for five years. He left the West Penn Railways Company three years ago and became electrical and mechanical engineer of the United Coal Company, one of the largest coal mining companies in Western Pennsylvania. About four months ago he accepted a position as manager of the Monongahela and Washington Street Railway Company, a new electric railway in course of construction between Monongahela and Washington, Pa. Mr. Bridge became an Associate of the Institute on January 27, 1905. The interment took place at Atlanta, Ga. He is survived by his widow and three children.

MR. GEORGE W. THOMPSON died suddenly at the Central Hotel, Hazelton Pa., on November 18, 1909. Mr. Thompson was born on July 9, 1867. Graduating from Swarthmore College in 1894, he entered the employ of the Lehigh Traction Company as superintendent, remaining with this company until 1905, when he went with the Westinghouse Electric and Manufacturing Company as salesman. Later he was appointed the head of the Wilkesbarre office of the company, which position he held to the time of his death. Mr. Thompson was admitted to membership in the Institute as an Associate on July 26, 1907.

MR. HARRY JOHN BUDDY, until recently manager of the light and power department of the Philadelphia office, General Electric Company, died at the Jefferson Hospital, Philadelphia, on January 15, 1910, of pleuro-pneumonia, after a short illness. Mr. Buddy was born in Philadelphia on March 23, 1865. In 1885 he entered the employ of the Thomson-Houston Company. Subsequently he went with the General Electric Company. He was elected an Associate of the Institute on June 19, 1903.

MR. JOHN C. REILLY, a Charter Member of the Institute, and a director of the New York and New Jersey

Telephone Company, died at his home in Brooklyn, on February 4, 1910, in his fifty-fourth year. Mr. Reilly was born in Lancaster, Pa. He was one of the pioneers in the telephone business, and in its earlier development was located in Philadelphia. He afterward went to Brooklyn, where he was active in developing extensions of the telephone service over Long Island. Mr. Reilly became associated with the Institute on April 15, 1884. He is survived by his wife, two sons, and two daughters.

Mr. George A. Joffe died in New York City on January 18, 1910. Mr. Joffe was born in Baku, Russia, on September 16, 1884, where he attended for a time the Charkoff Polytechnik. In 1904 he left Russia to complete his technical education in Paris, but through financial misfortunes was obliged to abandon his plans, and in January 1905 he sailed for America. He has since worked for the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., the Canadian General Electric Company, Peterboro, Ont., and the General Electric Company, Schenectady, N. Y., as draftsman and designer. Mr. Joffe was admitted to the Institute as an Associate on November 8, 1907. His parents survive him.

Mr. Fred Glyndon Tracy died recently at his home in Glyndon, Minn. Mr. Tracy was born on March 2, 1877. He was graduated from the University of Minnesota, class of 1900, with the degree of electrical engineer. From the time of his graduation until February 1904 he was in the employ of the Illinois Central Railway Company, as special apprentice, draftsman and testing expert, at Chicago. Failing health then obliged him to give up his employment, and he had since been the manager of the general store of C. G. Tracy and Company, at Glyndon, Minn. Mr. Tracy was elected an Associate on July 19, 1904.

Technical Sections

Various suggestions having been made regarding the formation of Technical Sections of the Institute, the subject was discussed at a meeting of the Board of Directors last fall and was referred to the Law Committee for a report. At the meeting of the Board of Directors held on November 12, 1909 the Law Committee presented the following report, which was accepted by the Board:

New York, November 9, 1909

Report of Law Committee on Proposed Formation of Technical Sections of the A. I. E. E.

Consideration of the proposed formation of Technical Sections naturally divides itself into two general headings; *Constitutionality*, and *Advisability, as a matter of policy.*

Constitutionality. Article IX. Sections 65 and 66 of the Constitution as amended May 21, 1907, is so broadly drawn as to be capable of being construed to mean either geographical or technical sections, although at the time these paragraphs were drawn, only the former were considered.

Sections 49, 50, 51 and 52 of the By-laws, however, distinctly refer to geographical sections only, so that they would require amendment before any action could be taken in reference to the formation of Technical Sections or Divisions.

Advisability, as a matter of policy. During the last year a great deal of attention has been given to the subject of Technical Sections, notably at the last convention at Frontenac, and as a result three distinct schemes to meet the situation arising from specialization along various lines within the scope of Institute activity, seem to have survived from the many proposed. These may be briefly summarized as follows:

Plan I. The formation of special committees, similar to the present sub-committees of the Meetings and Papers Committee. These additional committees would be appointed whenever the evolution of the art developed any

branch sufficiently to demand specialization by those engaged in it, and should have full charge of soliciting papers and providing discussions for as many special meetings as may be required to cover their subjects. These special meetings might also be held under the auspices of any of the Sections when considered advisable.

Under the present Constitution, *all* the papers presented, have to be approved by the Meetings and Papers Committee and all the discussions approved by the Editing Committee, and it seems that such a safeguard as this should surround anything published under the Institute's name.

This committee would suggest the advisability of the Meetings and Papers Committee holding its monthly meeting on a date fixed in relation to the Institute meetings, and also having a standing announcement in the PROCEEDINGS that all papers and discussions presented at meetings of the Institute or its Sections which had been received up to that date would be considered for publication in the issue of the PROCEEDINGS for the following month. All expenses of these special committees to be borne by the general funds of the Institute.

PLAN II. The formation of Technical Sections or Divisions, each of which would have its own officers and its own by-laws, with the maximum autonomy so long as no direct conflict occurred with the Institute Constitution or By-laws.

These sections would therefore be quite similar to the present geographical sections, but it would seem that there might be some organic difficulties due to possible conflict in dates of meetings or lack of coöperation between the technical and geographical sections. These Technical Sections would arrange for, and hold, their own meetings at such time and place as best suited the interests of the section.

Papers and discussions would be printed in the PROCEEDINGS when the Section officers so requested, but only those approved by the Meetings and Papers Committee would be printed in the TRANSACTIONS. All expenses of these Technical Sections would be borne by the general funds of the Institute.

As the Meetings and Papers Committee now have sole charge of meetings and papers, Plan II would involve an amendment to the Constitution.

PLAN III. The formation of as many independent societies as might seem necessary to cover the entire field of active specialization; all these societies to have their own officers, constitutions, by-laws and their own financial organization, and to carry on their own program of meetings and issue their own Proceedings.

These societies would affiliate with the American Institute of Electrical Engineers and through them exchange as many copies of their Proceedings as might seem desirable. The American Institute of Electrical Engineers would act as a clearing house for these publications and possibly take charge of the editorial and publication work for all. Just what the financial relationship between the parent and special societies would be, has not been definitely proposed, but presumably there would have to be some *per capita* payment to cover their share of the general executive expenses.

As each of these affiliated societies would have a large percentage of members who, for various reasons, would not be members of the American Institute of Electrical Engineers, some difficulty would be experienced in finding an equitable method of assessing their share of the American Institute of Electrical Engineers' expenses. This scheme seems to contemplate a relationship between the parent body and the special societies somewhat similar to our federal and state relationships, but with a restricted franchise instead of a universal one.

CONCLUSIONS

PLAN I is simply an extension of the existing organization of the Institute

and there seems no reason why such a plan could not be carried out successfully, provided the committee do their work thoroughly and enthusiastically.

PLAN II involves the publication of a large amount of additional matter, the volume of which would depend upon the activity of the Sections and their number.

Assuming that ten such Sections were organized, and that each one held six meetings per annum, or a total of 60 meetings, the cost of hall rent, stenographer, editing and printing the papers and discussions would probably average not less than $150.00 per meeting, or a total of $9,000 per annum.

The budget submitted by the Finance Committee, and approved by the Board of Directors on October 8, 1909 shows the estimated expenditures for the year beginning October 1, 1909 to be $76,925.

The Finance Committee further reported that they anticipated a surplus of receipts over expenditures for the year, amounting to approximately $3,000. From these figures it is apparent that the condition of the Institute's finances alone would render PLAN II impossible at present.

Parenthetically, it might be added that the Institute's executive expenses per member are much *less* than those of any other national engineering society, and that the amount spent upon meetings and papers and upon Sections is much greater, *per capita*, than in any other engineering society. It might be added that PLAN II has been tried by a sister society and the results obtained have not been such as to encourage them to form more than the first of these Technical Sections, as many difficulties in organization and in the relationship of the parent society to the section have arisen.

PLAN III, in the opinion of this committee, is inadvisable for the following reasons:

1. It is difficult to see what advantages would accrue to either the American Institute of Electrical Engineers or the affiliated societies from such a connection, as it would manifestly be impossible for the American Institute of Electrical Engineers to give to each and every member of the special societies a copy of its PROCEEDINGS and TRANSACTIONS, unless it was reimbursed for the cost of the same, or a fixed price per copy of the PROCEEDINGS charged. The Institute, if it acted as publisher and clearing house for the proceedings of all the societies, would have to assume serious financial responsibility for societies over which it had no control. The PROCEEDINGS can now be obtained without any affiliation, by subscription, or by Associate membership. On the other hand, the fact that a society was affiliated with the American Institute of Electrical Engineers would add nothing to the present standing of the American Institute of Electrical Engineers, but might affect that standing adversely if the affiliated society (over which the Institute would have practically no control) was lax in membership requirements.

2. The origin of all these suggestions was the fear that the formation of new special societies would gradually weaken the Institute by loss of membership. The actual facts, however, show that up to the present, the formation of these independent societies has in no way affected the Institute's membership or standing.

This committee believes that the formation of these special societies will follow as a natural result of the evolution of the art, and that the effect of their formation will be beneficial to the Institute, rather than detrimental, inasmuch as they will act as recruiting agents for the Institute, and at the same time furnish a channel for the presentation and discussion of papers which are too highly specialized to be of general interest to electrical engineers, and therefore not suitable for presentation before the Institute at large.

The broader field covered by the Institute will insure the presentation

before it of the fundamentally important papers.

Probably one of the most important educational features inherent to membership in the Institute is the wide range of subjects covered by the TRANSACTIONS. Take for instance, Volume XXVI (1907) and we find the following topics covered by papers and discussions:

1. Gas Engine Regulation for Direct Connected Units.
2. Underground Transmission of Electric Energy.
3. Economies of Railway Operation.
4. Phenomena of Abnormal Voltages on High Potential Lines.
5. Hydroelectric Plant Operation.
6. Alternating-Current Electrolysis.
7. Direct-Current Electrolysis.
8. Motor Generators, *vs.* Synchronous Converters.
9. Design of High-Potential Generators.
10. High-Voltage Systems for Interurban Railways.
11. Lightning Phenomena.
12. Rowland Telegraphic System.
13. Telephony.
14. Light from Gaseous Conductors.
15. Analysis of Distribution Losses.
16. Transformer Design.
17. Enclosed Station Wiring.
18. Electrostatics.
19. Theory (The Properties of Electrons).
20. Electrostatic, Electromagnetic and Chemical Data on Underground Cables.
21. Transformer Testing.
22. High-Tension Line Construction.
23. Switchboard Practice for 60,000 Volts and Upwards.
24. Choice of Frequency for Alternating Current Railways.
25. Proposed Code of Ethics.
26. Educational.
27. Theory and Design of Induction Motors.
28. Track Signaling.
29. Papers on Grounded Neutral.
30. Problems in Boiler and Furnace Design.
31. Exhaust Steam Turbines.
32. CO_2 Recorders.

Thus, in one year the Institute covered over twenty-five distinct topics with a series of most able papers and discussions, some of them classics in the literature of the art.

It should also be remembered that there would be some difficulty in getting engineers of national reputation to present or discuss papers before societies which were limited in membership to those engaged or interested in only one of the many branches of electrical engineering.

In conclusion, this committee feels that the most valuable assets of membership in the Institute are:

1. The PROCEEDINGS and TRANSACTIONS, which every member receives.

2. The education obtained by taking part in technical meetings covering all branches of the art, and

3. The friendships formed through social intercourse at these meetings.

The committee therefore considers that Plan III is not advisable. Plan II, in view of the experience of a sister society, is inadvisable, and not feasible, in the present state of the Institute's finances. Plan I is feasible and advisable, and your committee recommends that action be taken on these lines.

Respectfully submitted,

LAW COMMITTEE,

LOUIS A. FERGUSON.
J. W. LIEB, JR.
SAMUEL SHELDON.
PAUL SPENCER.
CHARLES A. TERRY
CALVERT TOWNLEY.
H. G. STOTT, *Chairman*.

November 9, 1909.

United Engineering Society

TREASURER'S REPORT

New York, January 27, 1910

To the Board of Trustees, United Engineering Society:

I beg to submit herewith report of the treasurer as of December 31, 1909.

From the balance sheet submitted herewith it appears that our physical property, over and above the value of the building and our equity in the land, consists of Real Estate Equipment, amounting to $16,767.72, and Furniture and Fixtures, $2,921.20.

It will be noted that the principal of the mortgage on the land, held by Andrew Carnegie, Esq., and amounting originally to $540,000, has been reduced by payments from the land and

building funds of the societies, to $223,000, correspondingly reducing the burden on the Founder Societies for payment of interest.

The gross operating expenses for the year were $35,845.92, or excluding expenditures for real estate equipment, $530, and furniture and fixtures to the amount of $682.86, a net cost of operating the building for the year 1909 of $32,163.57, slightly in excess of 1908.

In accordance with the resolution of the Board of Trustees, an appropriation of $5,000 was made out of the surplus remaining from the year 1908, and this amount ($5,037.50) was invested in Baltimore and Ohio Bonds, as an addition to the Contingency and Renewal Fund, as provided for in the Founders' Agreement bringing the Reserve Fund up to $10,268.75. It is recommended that a similar appropriation be made out of the available balance from this year's operations, leaving a surplus to be carried forward of $3,905.95.

Attention is called to the fact that we had on January 24, 1910, unoccupied floor space in the building equivalent in rental value to only 4 per cent of the total space available for assessment, and a part of this small remaining space is under option, so that the only space available and unengaged is the room and anteroom occupied by the trustees as a board room, and even that is occasionally called upon for board meetings under assessment for outside parties. One of the Founder Societies is prepared to release one or two rooms for applications from associate societies, otherwise the building may be deemed fully occupied.

Your attention is directed to the small number of times the auditorium has been occupied during the year—30 times as against 27 times in 1908—and the relatively small demand for the two assembly rooms on the fifth floor, occupied 56 times in 1909 as against 68 times in 1908. During the past year the facilities of the building were enjoyed by 52 societies, founder and associate, as against 34 in the year 1908. The limited use made of the auditorium and of the assembly rooms on the fifth floor, the income therefrom barely covering their quota of the fixed charges, continues to be a problem in the economical administration of the building.

The chief librarian reports a total attendance during the year of 8,303 as against 7,231 in 1908, the day attendance showing an increase of 750 and the evening attendance of 322.

The assessments paid for the year by the Founder Societies occupying one entire floor were $6,000 each, representing a total expenditure by each, including interest on its full principal of mortgage on the land, of $13,000, reduced in each case to the extent the society may have paid of part of its mortgage share. As the associate societies are assessed approximately $10,000 for equivalent facilities, it will be seen that the Founder Societies are still carrying more than their proportion of the carrying charges for equivalent office space occupancy in the building.

Respectfully submitted,
(Signed) J. W. Lieb, Jr.
Treasurer.

Balance Sheet, January 1, 1910

Assets

Real estate, land.....	$540,000.00		
Real estate, building..	1,050,000.00		
Real estate, equipment.............	16,767.72		
Furniture and fixtures.	2,921.20		
N. Y. City Bonds (cost) reserve......	5,231.25		
Balto. & Ohio Bonds (cost) reserve......	5,037.50		
Accounts Receivable..	3,357.00		
Library, United Eng. Society...........	29.05		
Library, adjustment account..........	30.56		
Cash:			
Working Balance		$5,099.88	
For Reserve Fund...		5,000.00	
Ways and Means Com....		1,165.08	
	11,264.96		
Petty cash..........	500.00		
			$1,635,139.24

LIABILITIES

Balance of Mortgage (Land) A.I.E.E.	$54,000.00	
Balance of Mortgage (Land) A.S.M.E.	81,000.00	
Balance of Mortgage (Land) A.I.M.E.	88,000.00	
		$223,000.00
A.I.E.E. Equity in Building		350,000.00
A. S. M. E. Equity in Building		350,000.00
A.I.M.E. Equity in Building		350,000.00
A.I.E.E. Equity in Real Estate equipment		3,346.61
A.S.M.E. Equity in Real Estate Equipment		3,346.62
A.I.M.E. Equity in Real Estate Equipment		3,346.62
A.I.E.E. payments to date in liquidation of Mtge on land		126,000.00
A.S.M.E. payments to date in liquidation of Mtge. on land		99,000.00
A.I.M.E. payments to date in liquidation of Mtge. on land		92,000.00
Depreciation and Reserve Fund		15,000.00
Ways and Means Committee, etc.		1,165.08
Accounts Payable		1,150.00
Balance, Cash, Accounts Rec., Furniture, etc		17,784.31
		$1,635,139.24

STATEMENT OF RECEIPTS AND DISBURSEMENTS
YEAR ENDING DECEMBER 31, 1909

RECEIPTS

Balance on hand January 1, 1909	$6,510.63	
Account Reduction of Mortgage on land	64,000.00	
Account Interest on Mtge.	10,740.00	
Assessment of Founder Societies	18,000.03	
Assessment of Associates, Offices, Meetings	27,363.29	
Library Account	5,109.27	
Interest on Bonds	225.00	
		$131,948.22

DISBURSEMENTS

Account Reduction of Mortgage on land	$64,000.00	
Account Interest on Mtge.	10,740.00	
Operating Expense, Cash Expenditures	30,445.39	
Real Estate Equipment	530.00	
Furniture and Fixtures	682.86	
Library Account	5,195.52	
Bonds purchased (reserve)	5,037.50	
Accounts Payable (from 1908)	1,399.37	
A.I.M.E. return of rentals for office	660.00	
Insurance	2,469.49	
Library adjustment	688.21	
Balance on hand, Jan. 1, 1910	10,099.88	
		$131,948.22

OPERATING INCOME AND EXPENSES YEAR ENDING DECEMBER 31, 1909

INCOME

Assessment Founders	$18,000.03	
Less A.I.M.E. refund	660.00	
		$17,340.03
Assessment Associates		16,746.00
Assessment Miscellaneous (Offices and meetings)		5,991.50
Telephone returns		2,620.70
Miscellaneous charges to societies		1,828.64
Interest		225.00
		$44,751.87

EXPENSES

Operating Expenses, gross	$32,163.57	
Real Estate Equipment	530.00	
Furniture and Fixtures	682.86	
Reserve Fund	5,000.00	
Insurance	2,469.49	
Balance to surplus	3,905.95	
		$44,751.87

SUPERINTENDENT'S REPORT OF MEETINGS AND ATTENDANCE, ENGINEERS' BUILDING,
For Year Ending December 31, 1909

	Meetings	*Attendance*
American Soc. of Mech. Engrs	13	2894
American Inst. of Elec. Engrs	9	2706
American Inst. of Mining Engrs	0	
N. Y. Electrical Society	7	631
N. Y. Railroad Club	9	4040
N. Y. Telephone Society	9	1865
Am. Soc. Heating and Ventg. Engrs	4	391
Blue Room Engineering Soc	12	310
Explorers Club	7	285
German Scientific Club	0	—
Western Electric Club	0	—
Technical Soc. of N. Y.	4	125
Am. St. & Inter. Railway Assn	3	80
Municipal Engineers of N. Y	9	1163
Illuminating Engrg. Society	12	1141
Soc. Naval Archts. & Marine Engs	2	199
Amer. Soc. of Refrg. Engineers	1	51
Railway Signal Association	1	203
C. I. Ftgs. Mfrs. Association	0	—
Underwriters Laboratories	0	—
Assn. of Edison Illum. Co's	1	7
Empire State Gas & El. Assn	2	66
U. S. Daughters of 1812	0	—
Reed Hollow Earth Explrs. Club	0	—
N. Y. Soc. Accountants & Bkprs	38	881
Musurgia Society	1	610
N. Y. Elec. Trade School	0	—
Am. Electro-Therapeutic Assn	7	303
American Gas Institute	0	—
Am. So. Promotion Indus. Education	0	—
Am. Ry. Master Mechanics	0	—
Amer. Geographical Soc	7	4708
N. Y. S. Assn. Opp. to Woman Suff.	2	25
Amer. Roentgen Ray Society	0	—
State of N. Y. Pub. Serv. Comm	8	315
Soc. Inter. Cong. Refg. Indust	1	25
So. For Pro. Engrg. Education	1	87

Joint Mtg. Consv. of Natl. Res.	1	625
Grand Conserv. of Music	1	19
Soc. of Automobile Engrg	1	83
Natl. Conf. on Stand. El. Rules	1	26
Natl. Assn. Str. Steel Fab'rs	1	39
Optometrical Society of N. Y	9	478
Theta Xi Fraternity	2	32
Am. So. Hungarian Engrs. & Archts.	7	79
Wireless Institute	8	203
Am. Soc. Engineering Contractors	3	67
American Railway Assn	1	205
Assn. Car Lighting Engrs	2	138
Aeronautic Society	2	213
Arctic Club	1	13
Tau Beta Pi	1	7
Total	211	25338

NUMBER OF TIMES MEETING ROOMS WERE USED DURING YEAR

Meeting Room.	*Times occupied*
Auditorium, 3d and 4th floors	30
No. 1 Assembly Room, 5th floor	26
No. 2 Assembly Room, 5th floor	48
Lecture Room No. 5, 6th floor	34
Lecture Room No. 6, 6th floor	11
Lecture Room No. 7, 6th floor	0
Lecture Room No. 8, 6th floor	46
Small Committee Room, 7th floor	37
Total	232

Associate societies occupying office space in building 17

Respectfully submitted,

Approved (Signed) JOHN LAMBDEN,
JOS. STRUTHERS, *Superintendent.*
Chairman House Committee.

National Civic Federation, Washington Conference.

New York, February 3, 1910

MR. LEWIS B. STILLWELL, *President*,
American Institute of Electrical Engineers,
100 Broadway, New York City.

DEAR SIR:

We have the honor to report that having been appointed by you as delegates to represent the American Institute of Electrical Engineers, we attended the National Conference on Uniform State Legislation, called by the National Civic Federation at Washington, D. C., January 17, 18, and 19, 1910. The several states and territories were represented by delegates appointed by their respective Governors, and there were also about eighty delegates representing various national civic organizations, making a total attendance of nearly five hundred delegates. Judge Alton B. Parker, of New York, was unanimously elected chairman of the conference, and through his very efficient guidance the conference was enabled to carry out its program with entire satisfaction to all. As the conference of the Governors was in session on January 17, an arrangement was made by which the twenty-five resolutions recommended by the conference were transmitted to that body by a special committee, of which the Honorable Seth Low was chairman. Through this channel it is believed that this movement in the direction of uniform legislation will receive substantial support. Any further action on the resolutions must lie with the legislatures of the several states; the framing of the proposed statutes will probably be undertaken by the commissioners on uniform state laws.

Among the resolutions adopted and transmitted to the Governors' conference, the following may be considered as being of interest to the electrical industry:

COMMISSION FOR OTHER THAN TECHNICAL OR LEGAL SUBJECTS

Resolved, that in the opinion of this conference it seems advisable that in the matter of a uniform tax law and in that relating to certain labor subjects upon which this conference favors uniformity and upon other subjects not technically of a legal nature, it is the opinion of this body that the drafting of these laws may well be considered by commissions specially appointed in the different states, the membership of which shall not be restricted to members of the legal profession, and that this action be communicated to the Governors.

CONSERVATION OF AMERICAN FORESTS

Resolved, That this conference endorses the conservation of American forests and

Whereas, the effective handling of forest land in private ownership depends mainly upon uniform state laws, providing for right methods of forest taxation and for the effective protection of forests from fire,

Resolved, That this matter be referred to the Commission on Uniform State Laws.

REGULATION OF WATER POWER

Whereas, the development of water powers is a subject of growing public importance, and the regulation looking to the uniform control of these powers by state and nation is a matter of public concern; therefore be it

Resolved, that this conference recommend to the commissioners on uniform state laws of the respective states the importance of the consideration of this subject, with a view to securing uniformity of state laws as to the regulation of water power on non-navigable streams, and the necessity of uniformity of state regulations as to water power on navigable streams, with the object of securing proper and uniform coöperation between each state and the federal government in the development and control of water power.

TAXATION

Resolved, that every state ought to have constitutional powers to classify property for taxation and that all the states ought to impose their taxes in conformity with such a system of comity between the states that there shall be no double taxation which shall be unfair or oppressive to any citizen.

UNIFORM INSURANCE CODE

Resolved, That we favor a uniform insurance code for adoption in the several states.

UNIFORMITY IN LEGAL PROCEDURE

Whereas, the system in vogue for the trial of causes in the criminal, equity and law courts of the United States and of the several states, is the subject of much current discussion, both lay and professional, and is severely criticised for its technicalities and its useless expense and delay; and

Whereas, the matter of procedural reform is receiving the thoughtful consideration of the American Bar Association through a special committee created for that purpose; therefore be it

Resolved, that this conference recognizes the need for radical changes in the administration of the law both in criminal and civil action;

Resolved, that a committee of fifteen on Reform in Legal Procedure, be created and appointed by the chairman of the Committee on Uniform Legislation of the National Civic Federation, and that such committee be instructed to cooperate with the committee of the American Bar Association to suggest remedies and formulate proposed laws to prevent delay and unnecessary cost in litigation, and to use the influence and power of the National Civic Federation to simplify, cheapen and expedite judicial procedure.

COMPENSATION FOR INDUSTRIAL ACCIDENTS

Whereas, the present remedies for compensation for industrial accidents throughout the various states are slow, uncertain, and wasteful and,

Whereas, there is not, and cannot be, any equitable solution thereof, based only on the fault of the employer, and

Whereas, twenty-three of the more progressive commercial nations abroad have bettered, and in some instance solved, the problem on the basis of workmen's compensation acts, and

Whereas, we believe that such acts can be adequately substituted for our present laws and applied to our institutions with equal satisfaction and profit,

Now, therefore, be it

Resolved, that this conference recommends to the Governors of the several states now assembled in this city, and to the states that workmen's compensation acts fair to the employer and employe and just to the state, be uniformly substituted for the present system of employers' liability for injuries received in and arising out of the course of employment.

It is of course understood that action of this conference can be nothing more than suggestive, and therefore active opposition to any of the resolutions will naturally remain dormant until they are actually brought before the law-making bodies of the various states for final enactment.

Respectfully submitted,

DUGALD C. JACKSON
J. W. LIEB JR.
RALPH W. POPE.
Delegates, American Institute of Electrical Engineers.

Hydroelectric Power Development in Russia

As a result of the development and successful operation of high-tension transmission lines in the United States, interest in electrical engineering progress in this country is rapidly growing in Russia. This has been stimulated by the recent investigations of Professor H. J. Ryan and Mr. Ralph D. Mershon. The Ministry of Ways and Communication at St. Petersburg has become interested in a scheme of hydroelectric power transmission which will involve the electrification of suburban divisions of the state railroads, and the subject is now under consideration. As some doubt seemed to exist in the minds of some of the officials as to the reliability of a 100,000-volt transmission line as compared with a 60,000-volt line, the latter being the highest in use in Europe, telegraphic inquiries have been made of some of the leading men in the electrical engineering profession in America as to the comparative merits and reliability of the two lines. Professor M. A. de Chatelain, of St. Petersburg, an Associate of the Institute, and

one of the most enthusiastic exponents of hydroelectric development in Russia, has been invited to make a demonstration of some high-tension transmission experiments with new types of insulators and different sizes of conductors before the officials interested. The advance of electrical engineering in Russia is likely to open a new and extensive field to American engineers.

Columbia University to Extend Classes

As a result of the success of the summer session of Columbia University, which in 1909 accommodated 2,000 students from all parts of the United States, it has been announced that beginning in September next the university will open extension classes in New York, Brooklyn, northern New Jersey and Westchester County. One of the features of the proposed plan is to provide classes and laboratory work in the evening at the university, and both in the evening and during the day at the various branches. This is mainly for the benefit of those who are not able to avail themselves of the regular courses of instruction at the university, and is in response to numerous and increasing requests for work of this kind during recent years. The field covered by this extension teaching will be very broad. There will be classes in languages, literature, history, economics, politics, and various scientific subjects, including electrical and mechanical engineering, architecture preventive medicine, the fine arts, teaching, and law. The entire undertaking will be under the supervision of Professor James Chidester Egbert, director of the summer session. Professor Egbert will also serve as director of extension teaching. Plans for the organization of the undertaking are going rapidly forward, and those desiring to have classes organized in any particular part of the city are requested to communicate with Professor Egbert at Columbia University.

Tungsten Lamp Tests

"Tests of Tungsten Lamps," by T. H. Amrine and A. Guell, issued as Bulletin No. 33 of the Engineering Experiment Station of the University of Illinois, presents the results of tests upon tungsten lamps of the 25-watt size. Of the three kinds of lamps tested, one kind was of American manufacture, with filaments made by the paste process, the other two kinds were of German manufacture, with filaments made by the colloid and deposition processes. Each type of lamp had a different scheme of filament mounting.

From these tests it is shown that

(1) When the lamps are subject to vibration, the life depends to a great extent upon the scheme of filament mounting, so that a lamp having its filaments mounted in such a manner that they are never under tension, gives a much better life, when subject to vibration, than one having tightly strung filaments.

(2) After burning 2000 hours under good conditions of operation, the average candle-power of the filaments made by the paste process decreased to 88 per cent; of the filaments made by the deposition process to 89 per cent; and of those made by the colloid process to 77 per cent of the initial value.

(3) The paste filament lamp, with loosely strung filaments, gives the longest life under both good and poor conditions of operation.

(4) The frequent breakage of the filaments during shipment and ordinary handling, and the early blackening of the bulbs, common in the early tungsten lamps, seem to have been overcome in all three types of lamps tested.

Copies of this bulletin may be obtained gratis upon application to W. F. M. Goss, Director of the Engineering Experiment Station University of Illinois, Urbana, Illinois.

Library Accessions*

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Mining Congress Proceedings Vol. 12. Denver, 1909. (Gift.)

American Railway Association. Statistical Bulletin Nos. 60, 63, 63-A. Chicago, 1910. (Gift.)

Cleveland Engineering Society. Journal Vol. II, No. 2, Dec. 1909. Cleveland, 1909. (Gift.)

Electric Heating and Cooking. (Carnegie Library of Pittsburgh.) Jan., 1910. Pittsburgh, 1910. (Exchange.)

Electric Railway and Lighting Properties. 1910. By Stone & Webster. Boston, 1910. (Gift of authors.)

La Fixation Industrielle de l'Azote. By P. A. Guye. n.p. n.d. (Gift of author.)

Forest Products of the United States, 1908. Washington, 1909. (Gift.)

General Electric Review. Vols. 1–3, Vol. 4, nos. 2, 3, 5, 6; Vols. 5–6; Vol. 7, nos. 1–3, 5–6; Vol. 8, nos. 1, 4, 5, 6; Vol. 9. Schenectady, 1903–1907. (Gift of General Electric Company.)

Magnetische Messungen. By E. Gehrcke und M. v. Wogau. (Reprint Ver. der Deut. Physikalischen Gesellschaft Yr. 11.) Braunschweig, 1909. (Gift.)

Metal Sleeve drum controller case. Lange & Lamme Patent no. 518, 693. Westinghouse Electric & Manufacturing Co., *vs.* Bullock Electric Manufacturing Co. (Bullock Order Nos. 1–3.) New York, 1910. (Gift of W. J. Jenks.)

——Bullock preliminary injunction. New York, 1910. (Gift of W. J. Jenks.)

New charter suggestions, submitted to the board of free-holders by the board of public improvements. (Engineers' Club of St. Louis, 1910.) (Gift.)

New York State Public Service Commission. First District. Annual report. Vols. 1–3, 1908. Albany, 1908. (Exchange.)

Oklahoma, State University. Research Bulletin Nos. 1–2. Norman, 1909. (Gift of State University of Oklahoma.)

Postulados de las clases obreras y de los desvalidos y proletarios, á presencia de la Ciencia Social y, en especial de la Economia Politica. (Vol. II Cong eso Cientifico 1° Pan-Americano.) Santiago de Chile, 1909. (Gift of the Secretaria General, 4° Congreso Cientifico.)

Recent Development of the Producer-Gas Power Plant in the United States. (Bulletin no. 416, U. S. Geological Survey.) By R. H. Fernald. Washington, 1909. (Exchange.)

Rugby Engineering Society. Proceedings Vol. 6. Rugby, 1909.

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——Testimonials. (Exhibit "A") n.p. n.d. (Gift Submarine Signal Company.)

——Lightship Equipment. (Exhibit "B"). n.p. n.d. (Gift Submarine Signal Company.)

——Signal Stations Required on Atlantic Coast, Great Lakes and Pacific Coast of the United States (Exhibit "C"). n.p. n.d. (Gift of Submarine Signal Company.)

Sydney University Engineering Society. Proceedings Vol. 13. Sydney 1909. (Gift of Sydney University Engineering Society.)

Uber den Zeemaneffekt in schwachen Magnetfeldern. By O. v. Baeyer und E. Gehrcke. (Reprint Annalen

*The Library Accession List published every month in the PROCEEDINGS includes additions to the Library of the Institute only. Similar accession lists of the Libraries of the American Institute of Mining Engineers and the American Society of Mechanical Engineers are published by those societies. Copies of these lists may be obtained without charge upon application to the secretary of the Institute.

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UNITED ENGINEERING SOCIETY

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American Machine Company, Louisville, Ky. Full magnet control electric elevators for passenger and freight service.

——Description of "American" Ammonia Regulator for refrigerating machines.

——Description of "American" Dehydrator for ice and refrigerating machines.

——Absorption system of ice making compared to the compression system.

——Catalogue of ice and refrigerating machinery absorption system.

Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines. (Bulletin no. 392, U. S. Geological Survey.) By R. M. Strong. Washington, 1909. (Gift of W. J. Jenks.)

Comparative Tests of Run-of-Mine and Briquetted Coal on the Torpedo Boat Biddle. (Bulletin no. 403, U. S. Geological Survey.) By W. T. Ray and Henry Kreisinger. Washington, 1909. (Gift of W. J. Jenks.)

Crystal and Solid Contact Rectifiers. By A. E. Flowers. (Reprint from the Physical Review, vol. xxix, no. 5, Nov. 1909.) (Gift of Missouri University.)

Eagle Almanac. 1909. Brooklyn, 1910. (Purchase.)

Electrical Fittings that have been examined by the Underwriters' National Electric Association. October, 1909. n. p., 1909. (Gift.)

Final Hearing of Selden Automobile Cases, on Selden Patent no. 549,160 for "Road Engine" Closing Argument for the Complainants by F. P. Fish, June 4, 1909. n. p., n. d. (Gift of Association of Licensed Automobile Manufacturers.)

Fustnélküli Város és az Ipar. By F. István. Budapest, 1907. (Gift.)

Hendricks' Commercial Register of the United States. Ed. 18th. New York 1910. (Purchase.)

Incidental Problems in Gas Producer Tests. (Bulletin no. 393, U. S. Geological Survey.) By R. H. Fernald, and others, Washington, 1909. (Gift of W. J. Jenks.)

Industrial Education. An address by Mr. Samuel P. Orth, Cleveland, 1909. (Gift.)

Insurance Society of New York. Bulletin no. 5, vol. 1. New York, 1909. (Gift.)

International Catalogue of Scientific Literature. Seventh Annual Issue. C-Physics. London, 1909. (Purchase.)

Lumber, Lath and Shingles, 1908. (U. S. Census Bureau Forest Products no. 2.) Washington, 1909. (Gift.)

Michigan Electric Light Association. Proceedings of 6th Annual Convention. Detroit, 1909. (Gift.)

Tribune Almanac. 1910. New York, 1910. (Purchase.)

Vilter Manufacturing Company, Milwaukee, Wis. Catalogue A. Refrigerating and ice making machinery. July, 1909. 61 pp.

——Catalogue F, Ammonia fittings for refrigerating and ice making plants. 112 p.

——Partial list of users of improved ice making and refrigerating machinery. April, 1909. 62 p.

Washington Society of Engineers. By-Laws, List of Officers and Members, February, 1909. (Gift of Society.)

World Almanac, 1910. New York, 1910. (Purchase.)

Trade Catalogues

Carnegie Steel Company. Data Appertaining to Light Rails and Fastenings. 1904.

——Pocket Companion containing Useful Information and Tables appertaining to the use of Steel manufactured by the Carnegie Steel Company. 1903.

——Shapes manufactured by Carnegie Steel Company. 1903 and supplement.

——Steel Mine Timbers. Data and tables for the use of Mining Engineers. 46 pp.

——Steel Sheet Piling. 16 pp.

——Schoen Steel Wheels, No. 1. 46 pp.

——Schoen Steel Wheels, Designs and Specifications. 46 pp.

——Carnegie special welding steel, Carnegie special threading steel. 40 pp.

——Carnegie steel cross tie and DuQuesne rail joint. 61 pp.

——Steel Sheet Piling—Types of construction and examples of installation. 64 pp.

——Steel Mine Timbers. Types of construction and examples of installation. 30 pp.

Cutter Electrical & Mfg. Co., Philadelphia, Pa. A to Z of the I-T-E circuit breaker. 54 pp.

General Electric Co., Schenectady, N. Y. Bulletin No. 4679A—Type D L C commutating pole motors. 8 pp.

——Bulletin No. 4706—Curve drawing ammeters and voltmeters—type C R construction. 4 pp.

——Bulletin No. 4707—Gasolene-electric generating sets for light and power. 24 pp.

——Bulletin No. 4713—Type F forms K-2 and K-4 oil break switches. 8 pp.

——Ornamental high efficiency arc lamps. 4 pp.

——Improved type H transformer. 1 pp.

——A view in the winding department of the transformer factory, Pittsfield, Mass. 1 pp.

Massachusetts Fan Co., Watertown, Mass. Squirrel cage fans. 12 pp.

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(Revised to January 1, 1910)

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Penn. State College...Dec. 20, '02	H. H. Agee.	H. E. Smith, Penn. State College, State College Pa.
Purdue Univ.........Jan. 26, '03	J. W. Esterline.	H. T. Plumb, Purdue University, Lafayette, Ind.
Rensselaer Polytechnic Institute.......Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y
Stanford Univ.......Dec. 13, '07	C. L. Bradley.	C. P. Taylor, Stanford University, California
State Agricultural Col. Feb 11, '10		
Syracuse Univ.......Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of......Feb. 14, '08	B. E. Kenyon.	J. A. Correll, University of Texas, Austin, Tex.
Wash., State Col. of..Dec. 13, '07		M. K. Akers, State Col. of Wash., Pullman, Wash
Washington Univ....Feb. 26, '04	H. F. Thomson.	George W. Pieksen, Washington University, St. Louis, Mo
Worcester Poly. Inst...Mar. 25, '04	Ray H. Taber.	C. E. Putnam, Worcester Poly. Inst., Worcester, Mass

Total, 30.

NOTE

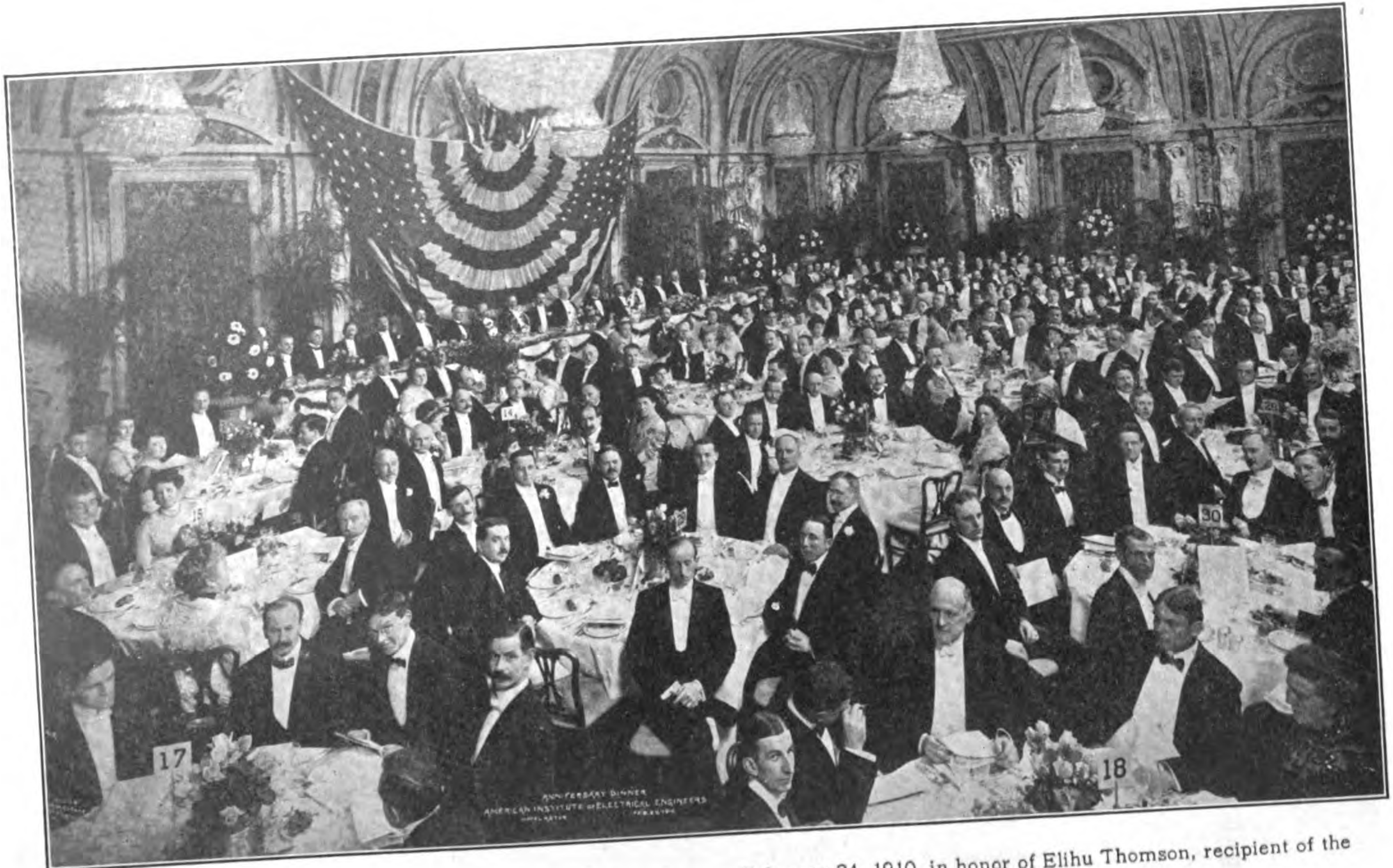
The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **Charlotte, N.C., March 30—April 1, 1910**. This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper so far in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, Chairman High-Tension Transmission Committee, 60 Wall Street, New York,** so that they will be received not later than March 25, 1910.



Annual Dinner of the American Institute of Electrical Engineers, February 24, 1910, in honor of Elihu Thomson, recipient of the Edison Medal for Meritorious Achievement.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York,

under the supervision of

THE EDITING COMMITTEE

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Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXIX **April, 1910** No. 4

Change in Date of Institute Meeting at San Francisco to May 5, 6 and 7, 1910

Circumstances have made it expedient to change the date of the proposed meeting at San Francisco, from April 21–23 to May 5, 6 and 7, 1910. The meeting will be under the auspices of the High-Tension Transmission Committee, and will be held in the auditorium of the Home Telephone Company's building, 333 Grant Avenue, San Francisco, Cal. There will be four professional sessions on the first two days, and a tour of inspection on the third day and several days of the succeeding week. The sessions will be held at 9 a.m. and 2 p.m. on May 5 and May 6, 1910. The following papers will be presented by their respective authors:

The Developed High Tension Network of a General Power System, by Paul M. Downing, engineer of operation and maintenance, Pacific Gas and Electric Company.

Hydroelectric Developments and Irrigation, by John Coffee Hays, consulting engineer, and president, Mt. Whitney Power Company.

Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants under Pacific Coast Conditions, by A. M. Hunt, consulting engineer and past-chairman, San Francisco Section A.I.E.E.

Through the courtesy of the several central California hydroelectric power companies, arrangements are being made for convenient visits to the more important standby plants and receiving stations in the San Francisco Bay region on Saturday, May 7, and to the transmission plants and mountain generating stations the first days of the succeeding week.

The high character of the papers which will be presented at this meeting, as well as the valuable discussion to be expected, should attract a large number of engineers, not only from the Pacific coast, but from other parts of the country. It is earnestly hoped that a representative attendance of the Institute membership will be present and participate in this meeting.

The opportunities afforded by the proposed tours for observing high-tension transmission practice in central California will add greatly to the interest.

The program has not as yet been fully completed, and Mr. Ralph D. Mershon, 60 Wall Street, New York City, chairman of the High-Tension Transmission Committee, Professor Harris J. Ryan, the California member of that committee, Stanford University, Cal., and Mr. S. J. Lisberger, secretary of the San Francisco Section, 445 Sutter Street, San Francisco, will cheerfully respond to all requests for additional information.

April Meeting at New York Postponed to April 15, 1910

The two hundred and forty-seventh meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Friday evening, April 15, 1910. The regular date for Institute meetings is the second Friday of each month, and in the March PROCEEDINGS it was announced that this meeting would be held on April 8. It has been found necessary to postpone the meeting one week, however, and it will therefore be held on April 15. The meeting will be under the auspices of the Educational Committee. Dr. Samuel Sheldon, professor of physics and electrical engineering, Brooklyn Polytechnic Institute, will present a paper entitled "Education for Leadership in Electrical Engineering." Some of the most prominent educators in the country are expected to attend and discuss this paper.

A.S.M.E. and A.I.E.E. Meeting, April 12, 1910

At the meeting of the American Society of Mechanical Engineers, to be held in the Engineers' Building, New York, April 12, 1910, the general subject will be the "Electric Drive." Through the Industrial Power Committee, the American Institute of Electrical Engineers will coöperate in this meeting and a paper will be presented by Mr. Charles Fair of the General Electric Company at Schenectady on "Motor Application to Machine Tools."

Institute Meeting at Charlotte, N. C., March 30 April 1, 1910

The 246th meeting of the Institute will be held at Charlotte, N. C., on March 30, 31 and April 1, 1910. The official headquarters will be at the Selwyn Hotel, which is on the European plan. Other hotels in Charlotte are: Buford Hotel, American and European plan; Stonewall Hotel, European plan; Central Hotel, American plan.

The program as now arranged is as follows:

WEDNESDAY, MARCH 30

MORNING SESSION—11 A.M.

Electric Drive in Textile Mills, by A. Milmow.

AFTERNOON SESSION—2 P.M.

Gas Engines in City Railway and Light Service, by E. D. Latta, Jr.

Visit to the textile mills and producer gas power plant.

EVENING SESSION—8 P.M.

Modifications of Hering's Laws of Furnace Electrodes, by A. E. Kennelly.

The Proportioning of Electrodes for Furnace Electrodes, by Carl Hering.

Some Demonstrations of Lightning Phenomena, by E. E. F. Creighton illustrated by experiments.

THURSDAY, MARCH 31.

MORNING SESSION—10 A.M

Economics of Hydroelectric Plants, by W. S. Lee.

AFTERNOON SESSION—2 P.M.

A Method of Protecting Insulators from Lightning and Power Arc Effects with Results of its Installation on the Lines of the Niagara and Lockport Power Company, by L. C. Nicholson.

[NOTE: Sequence of papers and the dates assigned are subject to change.]

ENTERTAINMENT

The Local Committee has made arrangements for the following events:

Wednesday afternoon, March 30, a visit to a few of the local cotton mills near Charlotte and a visit to the Producer Gas Power Plant of the Charlotte Consolidated Construction Company.

Thursday afternoon, March 31, a reception will be given by Mrs. Stuart W. Cramer to the visiting ladies.

Thursday evening, March 31, there will be a reception and dance at the Auditorium.

Friday, April 1, by courtesy of the Southern Power Company, which has kindly offered to furnish a special train,

a tour of inspection will be made of that company's Great Falls and Rocky Creek stations and a 100,000-volt substation. An old fashioned barbecue will be served while at Great Falls. This trip has been arranged so that the the party can return to Charlotte in the afternoon.

The Institute and its Local Sections

On January 14, 1910, the Board of Directors after careful consideration, adopted resolutions which have a most important bearing upon the future activity of the American Institute of Electrical Engineers. These resolutions were published in Section I of the PROCEEDINGS for February, but it is thought advisable in view of the fundamental and far reaching importance of the step which has been taken to call attention to them, and request the Institute membership to read them carefully and coöperate effectively to the end that the utmost possibilities of the Institute, conducted along broad lines as an organization in every sense continental and not local, may be realized. The principal objects which the Directors have had in view in developing the plan which is made effective by the resolutions referred to, are the following:

1. To afford all members of the Institute within reach of the headquarters of a local Section equal opportunity for the presentation of Institute papers and for participation in discussions.

2. To secure for the benefit of the Institute at large the results of the best thought and experience of its members by offering to members who generally find themselves unable to attend either the National Convention, or the Institute meetings hitherto usually held in New York, opportunity to present papers of Institute grade at regularly authorized Institute meetings held in cities within their convenient reach.

The Directors have realized the great importance of avoiding any step which might tend to lower the standard which hitherto has governed the Meetings and Papers Committees in accepting or rejecting papers submitted for presentation at Institute meetings and, in fact they are impressed by the belief that it is both practicable and wise, gradually to raise those standards.

A classification of the papers accepted for the Institute since 1902, the year in which the local Sections were established, affords evidence of the fact that convenient proximity to Institute meetings is an influential factor in securing papers of Institute grade from the membership. It is not to be expected of course that Sections whose membership consists of consulting engineers, operating engineers and instructors in educational institutions, scattered over a wide territory, should produce as many acceptable papers as originate, for example, in those great centers of electrical activity, Schenectady and Pittsburg. But undoubtedly members residing on the Pacific Slope, or in the Middle West, or in the South, engaged as some of them are in extensive applications of the electrical arts under varied conditions have in their possession material of great value which should be permanently recorded.

The resolutions of January 14 aim to place the membership of the Institute tributary to every and any local Section upon the same plane of opportunity in respect of presentation of papers as those members who happen to reside in the immediate vicinity of Institute headquarters.

Any local Section which may desire to have an Institute meeting held at its headquarters and under its auspices can attain that result by procedure practically identical with that which for many years has governed the Institute meetings held in New York. That procedure involves three steps:

1. Submission to the Meetings and Papers Committee of a paper or papers of Institute grade as determined by said Committee. Such papers must be forwarded to the Secretary of the Institute

not less than two months prior to date of presentation.

2. Approval by the Meetings and Papers Committee of the program and paper or papers to be presented at the proposed meeting.

3. Authorization of the meeting by the Board of Directors.

In all cases where Institute meetings may be thus authorized and arranged, advance copies of the accepted papers will be printed and issued in the usual manner.

So far as may be deemed practicable, officers of the Institute will preside at these meetings and in other cases the proper officers of the local Section under the auspices of which the meeting is held will preside.

It is earnestly hoped that the membership and particularly the officers of local Sections will avail themselves of the opportunity now presented to secure for the PROCEEDINGS papers of merit recording the results of experience on deduction, the publication of which will assist in advancing the art of electrical engineering.

LEWIS B. STILLWELL, *President.*

Joint Meeting at Boston, Mass., March, 11, 1910

The American Society of Mechanical Engineers held a meeting in Boston on Friday evening, March 11, 1910, in the Lowell Building, Massachusetts Institute of Technology, in coöperation with the Boston Section of the American Institute of Electrical Engineers. The subject of this meeting was a paper presented by Mr. M. W. Alexander, of Lynn, Mass., on "The Training of Men —A Necessary Part of a Modern Factory System." The paper was discussed at length by Messrs. Henry E. Rhoades, Charles F. Park, R. H. Smith, Ira N. Hollis, Gardner C. Anthony, Peter Schwamb, Luther D. Burlingame, G. C. Ewing, S. Fred Smith, and others. About 125 members of both societies were present. Copies of Mr. Alexander's paper may be obtained upon application to the Secretary.

A. I. E. E. Annual Dinner and Award of Edison Medal

The Annual Dinner of the American Institute of Electrical Engineers was held at the Hotel Astor, New York City, Friday, February 24, 1910, 278 guests being present. Professor Elihu Thomson was the guest of honor, and the dinner marked the celebration of the first award of the Edison Medal for meritorious achievement. Previous to the presentation of the medal to Professor Thomson an elaborate dinner was served in the large banquet room of the hotel, the electrical decorations of which were supplied by the New York Edison Company and the Edison Electric Illuminating Company of Brooklyn.

After the service of the dinner President Stillwell made a short address of welcome and introduced the Toastmaster of the evening, Past-president T. C. Martin. Mr. Martin opened the exercises by reading several telegrams of congratulation from friends of Professor Thomson, including Mr. Thomas A. Edison, Mr. B. E. Sunny, Mr. H. M. Byllesby and others.

The first toast of the evening was "Education and Invention" and was responded to by Professor Charles Baskerville, of the College of the City of New York. Mr. S. Insull was then called upon to respond to the toast "Meritorious Achievement in Electrical Engineering," and he paid high tribute to both Mr. Edison, in honor of whom the medal was founded, and Professor Thomson, the first recipient of its award. The toastmaster then called upon President Stillwell to speak on the toast "The Edison Medal," to which President Stillwell responded as follows:

ADDRESS OF PRESIDENT STILLWELL

The origin of the Edison Medal and the object which the members of the Edison Medal Association had in view in creating it, are described in the "Amended and Substitute Deed of Gift," as follows:

"The Edison Medal Association was organized for the purpose of appropri-

ately recounting and celebrating the achievements of a quarter of a century in the art of electric lighting, with which the name of Thomas Alva Edison is imperishably identified; and it seems to the association that the most effective means of accomplishing the object for which it was formed would be the establishment of an Edison medal, which should, during the centuries to come, serve as an honorable incentive to scientists, engineers and artisans, to maintain by their works the high standard of accomplishment set by the illustrious men whose name and features shall live while human intelligence continues to inhabit the world."

In accordance with the ideas thus set forth, the Edison Medal Association created a trust fund, procured a die for the production and reproduction of the medals and entered into a formal agreement with the American Institute of Electrical Engineers, among the provisions of which is the following:

"The Institute shall, through a committee to be duly appointed and authorized by it and known as the Edison Medal Committee, cause a gold medal to be executed, and shall award said metal to some one resident of the United States of America and its dependencies, or of the Dominion of Canada, for *Meritorious Achievement* in electrical science or electrical engineering, or the electrical arts, whenever in the judgment of said committee a resident of either of the said countries is properly deserving of such award."

The delicate and responsible duty of deciding when and to whom the medal shall be awarded is delegated by the Institute to a committee of 24 of its members, the by-laws providing for the appointment of this committee in a manner which effectively insures its competence and thoroughly representative character.

In this year, 1910, the medal is awarded for the first time—an event obviously of marked significance and import.

Twenty years ago three groups of men in America, standing in the forefront of development of electrical science and its practical application, were investigating, discovering and inventing with extraordinary energy and success. One of these groups was gathered about the man in honor of whom this symbol of success—the blue ribbon of achievement in the field of the electrical arts—was created.

Another group was led by the man upon whom, by the carefully weighed judgment of the American Institute of Electrical Engineers, that symbol is, for the first time, bestowed.

The third group was dominated and inspired by a man who sits to-night at this table, testifying by his presence that in extending the boundaries of knowledge into the realm of the unknown, the success of one means the success of all, and that success attained by one deserved and receives the applause of all.

The establishment and award of symbols such as the Edison Medal—concrete expressions of the recognition of real achievement in science or in its useful application, by those competent to judge—may well become a most potent influence for progress. It is unfortunate that in America, it is the fashion of the hour apparently to regard pecuniary profit as the only real and tangible prize to be attained by talent and industry. With us, attainment brings no bestowal of knighthood, no elevation to the peerage, no conference of the cross of an American Legion of Honor. If the daily press can be regarded as the index of popular thought, the general public regards the dollar as the sole, transcendant symbol of success.

Even among men of scientific training and thought, the tendency to overemphasize the practical applications, and regard too lightly the discovery of the scientific fact upon which that application depends, is far too general and every patriotic American must hope that the day will come when in the friendly competition of nations,

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our country will be distinguished no less for its contributions to pure science than for its practical application of laws and principles. Every influence, therefore, that can be brought to bear upon our young men to induce them to enter the lists of international competition in the world-wide effort to advance the frontiers of knowledge, deserves our approval and earnest coöperation. Our scientific societies should regard it as a duty imposed upon them by the position which they occupy in the community, to recognize, and in every proper way, emphasize and magnify the value of scientific work, considered entirely apart from its pecuniary results.

The Edison medal, awarded from year to year by the deliberate judgment of a jury, competent, conservative and judicial, is destined to become the most distinguished symbol of success in the field of electrical science. Established as a memorial to a man who, himself standing at the summit of achievement as an inventor, realizes as Newton did, the infinite possibilities beyond the boundaries of present knowledge, its award by the American Institute of Electrical Engineers is an honor which may well constitute, through the years to come, an incentive to ambition and stimulus to earnest endeavor.

At the close of President Stillwell's remarks the toastmaster called upon Mr. Charles L. Clarke, Chairman of the Institute Edison Medal Committee, to present the certificate of award, who spoke as follows:

The gold Edison medal for the year, 1909, and for the first time in the history of the medal, was awarded by the Institute on December 16, 1909, to Elihu Thomson. It devolves upon the Chairman of the Edison Medal Committee of the Institute to issue a certificate which shall constitute the official notice of award.

This certificate, with the gold medal, has been awarded to Elihu Thomson by the American Institute of Electrical Engineers.

The presentation inscription upon the document reads:

THE EDISON MEDAL

COMMEMORATING THE TWENTY-FIFTH ANNIVERSARY OF THE SUCCESSFUL INTRODUCTION AND COMMERICAL DEVELOPMENT OF THE INCANDESCENT LAMP

ESTABLISHED BY THE FRIENDS, ASSOCIATES AND ADMIRERS OF

THOMAS ALVA EDISON

ON HIS FIFTY-SEVENTH BIRTHDAY, FEBRUARY 11, 1904, IN THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, FOR MERITORIOUS ACHIEVEMENT IN ELECTRICITY

The certificate of award, as signed by the committee, is as follows:

"This Certifies that the Gold Medal has been awarded to Elihu Thomson for Meritorious Achievement in Electrical Science and Engineering, Engineering and Art, as exemplified in his contributions thereto during the past thirty years, by the American Institute of Electrical Engineers."

The Certificate is duly attested by the President and Secretary of the Institute, and by the Chairman and Secretary of the Edison Medal Committee.

In concluding the presentation, President Stillwell said, "I am happy that it has fallen to my lot as President of the Institute to announce the first award of the Edison medal, a symbol which is surely destined to become historic; and I am profoundly gratified that its recipient is a man whom our entire membership is delighted to honor, Dr. Elihu Thomson, to whom I now have the honor to hand the certificate of award of the Edison medal for meritorious achievement in electrical science, engineering and the arts, as exemplified in his contributions thereto during the past thirty years."

Professor Thomson responded as follows:

RESPONSE OF PROFESSOR THOMSON.

Mr. President, Mr. Toastmaster, ladies and gentlemen: No one could fail to be deeply moved by this kind

reception. I feel much as our past president, Mr. Martin, did about a year ago when he was made the recipient of a loving cup; he did not say anything, but I know it is expected of me to respond. I am on the program to respond and I, therefore, will try to do something in that direction.

Anything which I might say on this occasion could only express in small measure my appreciation of the honor done me in the award of the first Edison medal.

To be selected by such a representative body of men, distinguished in the electrical profession as the Edison Medal Committee, is itself a sufficient recognition; one to be prized most highly.

I most heartily thank the committee.

It is a source of great satisfaction that the award bears the name of the chief of pioneers in the field of large electrical application, the name of one to whose energy and courage, to whose ingenuity and resourcefulness the art owes so much.

I know that all present will agree that the name of Edison is peculiarly fitting to characterize an award given for electrical achievement. While the period of invention and technical advancement through which we have been recently passing has affected all fields, with none has the influence upon our conditions of life been more profound than with the applications of electricity.

When we look back to the early beginnings, we can realize the privilege of having lived at such a time so as to take some part in all that wonderful progress which has filled the succeeding years.

Who can enumerate the many conquests of man over nature's forces; the unlocking of the treasure house of knowledge of the universe around us? Through it man at last acquires the ability to navigate the air itself; an achievement which the most sanguine of us could scarcely have thought would come so soon.

Let us hope that all this is the beginning of an age of still greater advances, in which man will build more and more upon the foundations already laid.

I have sometimes been asked whether I did not like to read what may be called scientific fiction, in which an author tried to picture future scientific progress. I have usually answered " No, for truth is stranger than fiction ". It is the unexpected which happens. A speaking tube might suggest a telephone but what writer of fiction was there to predict that such an inexpressibly simple arrangement of wire and iron could transmit speech before Bell did it? Who of them told us of the wireless telegraph, and that an ordinary simple induction coil could stir the ether and transmit signals over hundreds of miles? What fiction writer had imagination so penetrating as to tell us that we could some day see our bones, and that surgery would be helped thereby? Who knew of the wonderful properties of radium, or ever imagined them possible? To come nearer home, who could picture, as the many triumphs of electrical engineering—a dozen or more different kinds of electric lights; transmission of thousands of horse power of energy over hundreds of miles, the electric railroad, and the other developments which in so short a time have far outstripped our most extravagant expectations?

As an instance of what was in the minds of people at the early inception of our art, I will read a little extract which I happened to find in one of the issues of the Gas Light Journal of 1878, when a discussion of the forthcoming Edison light, then the platinum wire lamp, was had. The following colloquy took place:

Mr. D. The gas we are now burning comes from Birchington, a distance of 1¼ miles. Would it be possible for me, if I wished to do so, to send electricity from here to Birchington to give light there?

Mr. G. It would be possible, but not economical.

Mr. D. Then how am I to light Birchington?

Mr. G. I should say, decidedly, take your machines to Birchington.

Mr. D. What am I to do for light along the road between here and Birchington?

Mr. G. Place machines at convenient distances.

Mr. D. In other words, several stations in such a short distance.

That was the view of a gas man, and actually occurred at a meeting of gas engineers at the time reported, and will be found in the Gas Light Journal.

I could go on and multiply instances of that kind, but that is merely a statement of conditions as they existed, and we have not time to go so far into accient history.

I have but little more to say in response.

I did not intend to make a speech of any length. I shall always value very highly the distinction which has been accorded me. But, however much one may be rewarded for doing that which his tastes and inclinations have led him to do, there is indeed another and more immediate reward, the hope of attaining, which is, after all, the strongest stimulus. I have sometimes referred to it as the " joy of accomplishment ". It is the sense of satisfaction which accompanies the doing of a thing, the surmounting of an obstacle, the attainment of a goal. It is the pleasure of having tried, and in spite of difficulties, succeeded. Those who have done this can understand what is meant. I confess that where a result is brought about by compelling taste or aptitude, in whole or part, the question of how much credit is to be accorded is not easy to determine. I am not arguing for the view of the ascetics that there belongs the greater credit to those who make themselves most miserable.

It is sometimes the case that a difficult thing is a sort of challenge, appealing to the imagination. After all, to the artist, the inventor, the scientific investigator, the engineer, and the broad man of business, imagination is often the chief mainspring of action. It enables him mentally to picture a thing as done or accomplished before the doing, and so to seek out the plan to be followed or the measures to be taken. Imagination furnishes the dreams that may come true. They are carried into practice and if the things done are worth while, success and its accompanying " joy of accomplishment " follow.

What matters it that there are many and unlooked-for hardships, setbacks and struggles against adverse circumstances, if the end in view is at last attained. There will always be need of energy, self-denial and persistence, if we would follow out our plans. Too often success is measure by financial outcome and this we must guard against. We need the broader view which causes us to sympathize with all progress and assist in it.

I wish now to add that in honoring me, you should not forget that there were faithful co-workers, some of whom I see now here, without whose help, at times when it was most needed, much less would have been accomplished. I mean also to include in this, those through whose wisdom and business sagacity the means were provided for doing such things as seemed needful at the time. To them a high tribute is due for they contributed in large measure to render possible that for which the Edison medal has been so graciously accorded.

Ladies and gentlemen, members of the Institute, I thank you all with the utmost sincerity for the honor you do me in being present on this occasion.

The ceremony was concluded by a brief speech from toastmaster Martin who announced that copies of the medal in bronze would be passed around for inspection.

Steam Turbine Economy

A meeting of the American Society of Mechanical Engineers with the coöperation of the American Institute of Electrical Engineers was held in New York on March 8, 1910, at which Past-president Henry G. Stott, of the

A.I.E.E., read a paper on "Tests of a 15,000-kw. Steam-Engine-Turbine Unit." A limited number of copies of this paper are available for distribution, and will be sent to members upon request until the supply is exhausted. Members desiring copies should address the secretary, Ralph W. Pope, 33 West 39th Street, New York City.

Institute Meeting at New York March 11, 1910

The two hundred and forty-fifth meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers Building, 33 West 39th Street, New York City, on Friday evening, March 11, 1910. The meeting was under the auspices of the Industrial Power Committee, and was called to order by President Lewis B. Stillwell at 8:20 p.m. The Secretary announced that at the meeting of the Institute Board of Directors held during the afternoon, 101 Associates were elected, and four Associates were transferred to the grade of Member. The report of the Committee of Tellers was then read, and the names of the Directors' Nominees were announced. The ticket, as prepared at the meeting of the Directors in the afternoon is printed elsewhere in this issue. President Stillwell then briefly outlined the program for the evening, which consisted of three papers presented in the following order:

"Electric Mine Hoists", by D. B. Rushmore and K. A. Pauly;

"Electric Mine Hoists", by Wilfred Sykes;

"Electric Mine Hoists with Ilgner Motor Generator Set", by R. R. Seeber.

The presentation of these papers was accompanied by numerous lantern slides.

The Avalanche at Cascade Tunnel

Our readers will recall the paper presented by Dr. Cary T. Hutchinson at the Institute meeting in New York on November 12, 1909, which appeared in the November PROCEEDINGS, on the electric system of the Great Northern Railway at Cascade Tunnel. It may not be generally known that the avalanche which occurred at Wellington, at the western end of the tunnel, on March 1, caused considerable damage to the equipment of the system. All four of the electric locomotives, with two trains, three steam locomotives, and a rotary snow-plow, were swept away by the slide. Some idea of its force may be gained from the fact that the weight of each of the electric locomotives is 230,000 lb. A portion of the overhead catenary construction was also swept away. The extent of the damage to the electric locomotives has not yet been determined. If much of the apparatus has to be rewound, it may be six months before the electric service can be resumed, as the locomotives will probably have to be sent to Seattle or some other city for repair.

Nominations for Offices, 1910

In conformity with the Constitution, President Stillwell appointed in February a Committee of Tellers to count the nomination ballots cast for the offices to be filled at the close of the present administration year. The committee was constituted as follows: Messrs. G. A. Baker, chairman, A. A. Frank, William Nesbit, C. K. Nichols, and S. N. Castle. Having completed this work, the committee submitted its report to the Institute Board of Directors at the meeting of the Board held on March 11, 1910. This report, which is a summary of the nomination ballots cast, is printed herewith:

GENERAL PROPOSAL LIST

FOR PRESIDENT

Dugald C. Jackson	728
Calvert Townley	35
C. C. Chesney	34
Scattering	160
Blank	138
Total	1095

FOR VICE-PRESIDENTS

P. H. Thomas	325
H. W. Buck	300
B. G. Lamme	265
Morgan Brooks	196
A. M. Schoen	148
E. J. Berg	49
Scattering	627
Blank	1375
Total	3285

FOR MANAGERS

Henry Floy	226
H. H. Barnes, Jr.	207
C. E. Scribner	191
N. W. Storer	137
W. S. Rugg	127
N. J. Neall	114
R. G. Black	100
H. B. Smith	99
J. F. Stevens	58
E. J. Berg	50
W. F. Wells	47
H. S. Putnam	44
P. Junkersfeld	41
H. N. Latey	41
A. M. Hunt	40
Scattering	1013
Blank	1845
Total	4380

FOR TREASURER

Geo. A. Hamilton	860
Scattering	12
Blank	223
Total	1095

FOR SECRETARY

Ralph W. Pope	864
F. L. Hutchinson	51
Scattering	3
Blank	177
Total	1095

Names of members who received less than 3 per cent of the entire number of votes cast have been omitted from the above list in accordance with Article VI, Section 31 of the Constitution.

From this list the Board of Directors, in accordance with Section 31, Article VI, of the Constitution, prepared its ticket, as follows:

DIRECTORS' NOMINEES

For President.....Dugald C. Jackson

For Vice-presidents
H. W. Buck.
Morgan Brooks.
P. H. Thomas.

For Managers.....H. H. Barnes, Jr.
R. G. Black.
W. S. Rugg.
C. E. Scribner.

For Treasurer.....George A. Hamilton.

For Secretary.....Ralph W. Pope.

The election will take place at the annual meeting of the Institute, on May 17, 1910. Voting is restricted to the names of the Directors' Nominees and the names on the General Proposal List. To be valid, ballots must reach the secretary's office not later than May 1, 1910.

Directors' Meeting, March 11, 1910

The regular monthly meeting of the Institute Board of Directors was held at 33 West 39th Street, New York City, on Friday, March 11, 1910. The directors present were: President Lewis B. Stillwell, New York; Past-president Henry G. Stott, New York; Vice-presidents C. C. Chesney, Pittsfield, Mass., Bancroft Gherardi, New York, Calvert Townley, New Haven, Conn., P. M. Lincoln, Pittsburgh, Pa., Paul Spencer, Philadelphia, Pa.; Managers H. W. Buck, New York, Percy H. Thomas, New York, David B. Rushmore Schenectady, N. Y., W. G. Carlton, New York, H. E. Clifford, Cambridge, Mass., A. W. Berresford, Milwaukee, Wis., W. S. Murray, New Haven, Conn., H. H. Norris, Ithaca, N. Y.; Secretary Ralph W. Pope, New York.

One hundred and one candidates for admission to membership in the Institute were elected.

Ninety-eight Students were declared enrolled.

Four Associates were transferred to the grade of Member, as follows:

FRANK M. TAIT, engineer and general manager, Dayton Lighting Company, Dayton, Ohio.

LOUIS C. MARBURG, electrical and mechanical engineer, Allis-Chalmers Company, Milwaukee, Wis.

ROBERT B. WILLIAMSON, electrical engineer, Allis-Chalmers Company, Milwaukee, Wis.

THOMAS COMMERFORD MARTIN, Executive Secretary, National Electric Light Association, 29 West 39th Street, New York City.

In accordance with Section 31, Article VI, of the Constitution, there was prepared at this meeting the Directors' Nominees ticket for the offices falling vacant at the close of the present administration year as printed in another column.

Associates Elected March 11, 1910

AFFOLTER, PAUL HENRY, Inspector, Laramie Electric Company, Laramie, Wyoming.

ALLAN, WILLIAM GEORGE, Electrical Engineer and Draughtsman, Ferranti, Ltd.,Hollinwood,Lancashire,England.

ALLEN, HENRY VAN DYKE, General Electric Company, Schenectady, New York.

ANDREWS, EDGAR W., Southern Power Company, Trust Building, Charlotte, N. C.

BAKER, ROSS LEE, Superintendent Line Department, Empire District Electric Co., Joplin, Missouri.

BIVENS, JOE PITTMAN, Electrician, Columbia University; res., 247 West 23rd St., New York City.

BLAUVELT, WILLIAM GROVE, American Telephone and Telegraph Company, 15 Dey St., New York City.

BOE, HARRY FOSTER, Tester, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.

BRADLEY, JOHN C. G., Salesman, Westinghouse Electric & Mfg., Co., 121 E. Baltimore St., Baltimore, Md.

BRIMSON, GEORGE JAMES, Foreman of Regulator Department, General Electric Co., Pittsfield, Mass.

BROWN, BEDFORD JETHRO, Electrical Engineer, Southern Power Co., Charlotte, N. C.

BROWN, BRIGGS ODD, United States Engineers Dept. at Large, Room 321 Custom House, Portland, Oregon.

BUCHERT, EMIL, Electrical Draughtsman, Public Service Corporation of New Jersey, res., 43 Fairview Ave., Newark, N. J.

BULL, EDMUND WILLIAM, City Electrician, Electrical Department, Regina, Saskatchewan, Canada.

BURCHER, REGINALD HILLIARD, Division Plant Engineer, New York Telephone Co., 547 Clinton Ave., Brooklyn N. Y.

BURKE, JOSEPH HENRY, Chief Inspector, Electrical Bureau, Dept. of Water Supply, Gas and Electricity, Long Island City, N. Y.

CALDWELL, LON DONALDSON, Superintendent, Water and Light Department, Kings Mountain, N. C.

CALVERT, JOHN EDWARD, Substation Foreman, Pacific Gas and Electric Co., Grass Valley, Cal.

CANTIN, ARTHUR J., Circuit Draftsman, Western Electric Co., Hawthorne; res., 3016 W. Congress St., Chicago, Ill.

CARLTON, HARRY, Transformer Engineering Dept., General Electric Co.; res., 8 Abbott St., Pittsfield, Mass.

CHAPMAN, DAVID ALBERT, Superintendent, Estate of E. S. Converse, 101 Milk St., Boston; res., 163 Grover Ave., Winthrop, Mass.

CHEDSEY, WILLIAM REUEL, Associate Professor of Mining Engineering, University of Idaho, Moscow, Idaho.

CLAYTOR, WILLIAM GRAHAM, Electrical Engineer, Roanoke Railway & Electric Co., Roanoke, Virginia.

CONNELLY, RALPH PERKINS, Inspector, Southern Power Company; res., 571 West 7th St., Charlotte, N. C.

CULBERTSON, ROY KIRKWOOD, Engineer Westinghouse Electric & Mfg. Co., Pittsburg; res., 413 South Ave., Wilkinsburg, Pa.

CURRY, CURTIS CHASE, Agent, Westinghouse Electric & Mfg. Co., 936 Metropolitan Life Bldg., Minneapolis, Minn.

CURTIS, WILLIAM F., Manager, The Colonial Electric Co., 136 Liberty St., New York City.

DATE, WILLIAM E., Engineer, The Cutler-Hammer Mfg. Co., 50 Church St., New York City.

DAVIS, FRED REYNOLDS, Chief Engineer, Charlotte Consolidated Construction Co., Charlotte, N. C.

DEFENBAUGH, HOMER CROW, Electrical Engineer, Rochester Railway and Light Co., 34 Clinton Ave., N. Rochester, N. Y.

DISHINGTON, JOHN ROBERT, Superintendent of Lighting, The Milwaukee Electric Railway and Light Co., Racine, Wis.

DYER, EARL KENNETH, Telephone Engineer, Railway Dept., Western Electric Co.; res., 1818 W. 21st St., Los Angeles, California.

EDGELL, FRED VICTOR, Manager, Folsom Tea Company, 269 Broadway, South Boston, Mass.

EGY, WILLARD LEO, Assistant Engineer, Underwriters' Laboratories, 207 East Ohio St., Chicago, Ill.

FARNSWORTH, PHILIP, Patent Lawyer, 42 Broadway, New York City; res., Summit, N. J.

FISK, IRA WILLIAM, Assistant in Electrical Engineering, University of Illinois, Urbana, Ill.

FORBUSH, WALTER ALFRED, Edison Electric Illuminating Co. of Brockton, Bridgewater, Mass.

FORSYTHE, ROBERT LEO, Electrician Enterprise Electric Company, Enterprise, Oregon.

FRENCH, EDWARD RUTLEDGE, Superintendent Central Division, Public Service Corp., 71 Murray St., Elizabeth, N. J.

GASCHE, FERD GUY, Mechanical Engineer Illinois Steel Company, South Chicago, Illinois.

GATCHELL, FREDERICK D., Superintendent and Purchasing Agent, Charlotte Electric Railway, Charlotte, N. C.

GRAFF, SHELDON DERMITT, Salesman, Simplex Electrical Co., 201 Devonshire St., res., 15 Blagdon St., Boston, Mass.

GRAHAM, EARL ADDISON, Construction Engineer, Canadian Westinghouse Co., Ltd., Hamilton, Ontario.

GRIFFITH, M. J., Superintendent of Construction, Westinghouse Church, Kerr & Co., New York City; res., 22 James St., Wilkes-Barre, Pa.

GUNBY, FRANK MCCLELLAN, Electrical Engineer, with Chas. T. Main, 45 Milk St., Boston, Mass.

HALLBORG, HENRY EMANUEL, Engineer, National Electric Signaling Co., Brant Rock, Mass.

HANKS, WILLIAM WALLACE, Superintendent Charlotte Power Company, Trust Building, Charlotte, N. C.

HARDIN, JAMES OTEY, Assistant, Electrical Engineering Laboratory, University of Tennessee, Knoxville, Tenn.

HARRISON, JAMES, Manager, Southern Department, Doubleday-Hill Electric Co., Charlotte, N. C.

HENLEY, LLOYD, Construction Department, Pacific Gas and Electric Co., Oakland, California.

HICKS, ALFRED TAVERNER, Local Manager, The Trenton Electric & Water Co., Trenton, Ontario.

HIRSCH, JOHN GEORGE, Assistant Engineer, with Daniel W. Mead; res., 118 W. Dayton St., Madison, Wis.

HOLLENBECK, BRUA ARNOT, Designing Engineer, Western Electric Co., Hawthorne; res., 1812 S. Lawndale Ave., Chicago, Ill.

HUDGINS, JOHN DOUGLAS, Electrician, United States Naval Experiment Station, Annapolis, Maryland.

HYER, RAYMOND GASKILL, Foreman of Construction, Westchester Lighting Co.; res., 329 Rich Ave., Mt. Vernon, New York.

IRWIN, BATTE, Mill Power Department, Southern Power Co.; res., 401 N. Tryon St., Charlotte, N. C.

JOHNSON, PHILLIP HAFFORD, Assistant in Electrical Engineering, University of Wisconsin, Madison, Wis.

JOHNSTON, WILLIAM D., Division Superintendent of Plant, Central District and Printing Telegraph Co., Butler, Pa.

KENYON, JARED SHOTWELL, Electrical Engineer, Diehl Manufacturing Co., Elizabethport, N. J.

KERR, WILLIAM CAMPBELL, Mechanical Engineer, Philadelphia Rapid Transit Co., 9th & Dauphin Sts., Philadelphia, Pa.

KEYES, EDWIN FRANK, Instructor in Electrical Engineering, Washington State College, Pullman, Wash.

KEYS, HARRY MONTIFIX, Engineer, The Southern Bell Telephone and Telegraph Co., Atlanta, Ga.

KILBURN, ERNEST EDWIN, Electrical Engineer, Standard Engineering Co. 54 Center Street, Waterbury, Conn.

KIMBRELL, MARVIN REA, Southern Power Company; res., 312 N. College Street, Charlotte, N. C.

KNIPMEYER, CLARENCE CARL, Assistant Professor of Electricity, Rose Polytechnic Institute, Terre Haute, Ind.

LATHAM, EDWARD W., Chief Inspector, Bureau Electrical Inspection, Room 33a Municipal Bldg., Brooklyn, N. Y.

LATTA, ALBERT WHITEHEAD, Salesman, General Electric Company, 506 Trust Building, Charlotte, N. C.

LAWTON, ARTHUR, City Engineer, Oakland, California.

LOVE, FRED BARRETTE, Electrician, Buckeye Electric Company, Court House Square; res., 201 Clinton Court, Findlay, Ohio.

MACNAUGHTON, DAVID, Superintendent of Meter Department, Milwaukee Electric Railway and Light Co., Milwaukee, Wis.

MARGUERRE, FRITZ B., Chief Electrical Engineer, Norsk Kraftahtieselskal and Aktieselskab Norske Saltpeterveher, Kristiania, Norway.

NAUL, JAMES MYRVEN, Motor Engineer, General Electric Company; res., Woodlawn Inn, Pittsfield, Mass.

NICHOLS, FRED AUGUSTUS, Electrical Engineer, International Railway Company, 1026 Niagara Street, Buffalo, N. Y.

OSTRANDER, JOHN K., Assistant Electrical Engineer, A. L. Drum & Co., 624 American Trust Bldg., Chicago, Ill.

OSWALD, FRED, Manager, Buckeye Electric Company, Court House Square; res., 615 W. Sandusky St., Findlay, Ohio.

OWENS, SAMUEL HAYDEN, Stationary Engineer, Southern Power Company, Charlotte, N. C.

PACE, JOHN DOUGLAS, Electrical Engineer and Operating Superintendent, Cobalt Power Co., Cobalt, Ontario.

PARKER, CHARLES SHIRECLIFF, Station Operator, The City of Seattle Lighting Department, North Bend, Wash.

PERRY, FREDERICK GARDINER, Electrical Assistant, Boston Elevated Railway Co., 552 Harrison Ave., Boston, Mass.

PETTY, DAVID M., Electrician, Bethlehem Steel Company, South Bethlehem, Pa.

POLLOCK, ROBERT THOMAS, General Manager, Universal Carbon Company, Ashland, Mass.

REINHARD, LOUIS FERDINAND, Chief Engineer, Mechanical Appliance Co., 133 Stewart St., Milwaukee, Wis.

RICHARDSON, EDWARD BRIDGE, Partner, Richardson & Hale, 85 Water Street, Boston, Mass.

RICHARDSON, GEORGE EDWARD, Salesman, General Electric Company, 84 State St., Boston, Mass.

RUTLEDGE, GEORGE HAMILTON, Manager and Superintendent, Concord Water & Light Co., Concord, N. C.

SAMUKAWA, TSUNESADA; Chief Electrical Engineer, Hakone Water Power Co., Dengyoshia, Uchisaiwaichuo, Kogimachi-ku, Tokyo, Japan.

SANFORD, RAYMOND LARAWAY, Instructor in Electrical Engineering and Physics, University of Vermont, Burlington, Vt.

SEARLE, EDWARD, Coes Wrench Company; res., 591 Park Avenue, Worcester, Mass.

SENOUR, DANIEL Z., Designing Engineer Western Electric Co., Hawthorne; res., 6033 Drexel Ave., Chicago, Ill.

SLOCUM, BENJAMIN W., Chief Engineer of Steam Stations, Portland Railway, Light & P. Co., 7th & Alder Sts., Portland, Ore.

SMELTZER, LAWRENCE WALTER, Electrician, Automatic Electric Co., Morgan and Van Buren Sts., Chicago, Ill.

SOULE, WILLIAM HORNSBY, Assistant, Engineering Department, Allis-Chalmers-Bullock Ltd., Montreal, Canada.

SPRUNT, HERBERT WILLIAM, Chief Engineer and Manager, The South London Electric Supply Corporation Ltd., London, Eng.

STARRETT, JOHN PHINEAS, Engineer, D. C. and W. B. Jackson; res., 45 Hancock Street, Boston, Mass.

SYMINGTON, SCOTT, Engineer, The Christchurch Tramway Board, Christchurch, N. Z.

TATE, ALFRED ORD, President, Tate Accumulator Company of Canada, Ltd., Toronto, Canada.

TOWNSEND, FRANK PILGRIM, Electrical Engineer, The National Tube Co., Lorain; res., 507 West Ave., Elyria, Ohio.

TRACY, EVERET GRANT, Testing Department, General Electric Co.; res., 822 State St., Schenectady, N. Y.

VINCENT, JOHN JAMES, Chief Engineer, Lyttleton Times Co., Christchurch, New Zealand.

WILLSON, EDWIN LAWRENCE, Assistant Electrical Engineer and Chemist, The Hazard Mfg. Co., Wilkes-Barre, Pa.

WOOTTEN, EDWARD YONGE, Erecting Engineer, Westinghouse Electric & Mfg. Co., Charlotte, N. C.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at its regular monthly meeting held on March 11, 1910. Any objection to the transfer of these Associates should be filed at once with the secretary.

MAX P. COLLBOHM, electrical engineer, Madison, Wis.

THOMAS WEST GARDNER, chief electrical engineer, Cumberland Telephone and Telegraph Company, Nashville, Tenn.

SIMON B. STORER, consulting electrical engineer, Syracuse, N. Y.

WARREN H. FISKE, electrical engineer, Mexican Light and Power Company, Mexico City, Mex.

CHARLES T. MOSMAN, electrical engineer, General Electric Company, Boston, Mass.

I. E. HANSSEN, electrical engineer, Moss, Norway.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before April 20, 1910.

9349 Skogland, D., Chicago, Ill.
9350 Baker, G., Schenectady, N. Y.
9351 Heine, J. F., Washington, D. C.
9352 Mulholland, B. F. P., Toronto, Ont
9353 Mullen, W. G., Baltimore, Md.
9354 Walling, B. T., New York City.
9355 Deesz, L. A., Cripple Creek, Col.
9356 Leffingwell, W. H., Bishop, Cal.
9357 Macdonald, R. R., Toronto, Ont.
9358 McCabe, J., Greenville, S. C.
9359 Sands, H. T., Malden, Mass.
9360 Scholz, W. P., Jr., New York City.
9361 Snyder, W. T., McKeesport, Pa.
9362 Wood, W. M., Portland, Ore.
9363 Heyl, R. G., Baltimore, Md.
9364 Irvine, T. F., Pittsburg, Pa.
9365 Klemm, C. A., Louisville, Ky.
9366 May, E. S. C., New York City.
9367 Noble, E. E., Cleveland, O.
9368 Olmstead, F. W., Brooklyn, N. Y.
9369 Saltz, L. W., Cleveland, O.
9370 Steele, G. F., Boston, Mass.
9371 Stevens, H. W., Boston, Mass.
9372 Townsend, A. J., Morrisburg, Ont.
9373 Trout, S. B., Tacoma, Wash.
9374 Wilkins, A. O., Brattleboro, Vt.
9375 Andrews, E. L., New York City.
9376 Appleton, A. T., Port Colburne, Ont.
9377 Drummond, Wm., Lincoln, Neb.
9378 Hunt, Raymond, Wilmington, N.C.
9379 McNutt, R. H., Schenectady, N.Y.
9380 Salt, A. L., New York City.
9381 Staege, S. A., Syracuse, N. Y.
9382 Starr, H. W., Schenectady, N. Y.
9383 Burnett, R. S., Jersey City, N. J.
9384 Carey, W. G., Schenectady, N. Y.
9385 Houseworth, W. H., Jr., Pasadena, Cal.
9386 Owen, A. C., Dunedin, N. Z.
9387 Peebles, F. W. L., St. Louis, Mo.
9388 Steinfort, C. E., Eau Claire, Wis.
9389 Townsend, H. D., Youngstown, O.

9390 West, John, Joplin, Mo.
9391 Bixby, H. E., Topeka, Kansas.
9392 Chaffee, W. N., Pittsburg, Pa.
9393 McBrian, E. W., Macon, Ga.
9394 Morgan, W. B., Dawson, Y. T.
9395 Rapelje, H. de W., Wilmington, N.C.
9396 Tarnbert, E. E., Los Angeles, Cal.
9397 Widenmann, W. A., Berkeley, Cal.
9398 Willis, F. Le R., Leadville, Colo.
9399 Anderson, S. H., Los Angeles, Cal.
9400 Hayes, George, Boston, Mass.
9401 Manhart, G. H., Minidoka, Idaho.
9402 Robb, A. D., Niagara Falls, Ont.
9403 Vatter, W. L., New York City.
9404 Mason, F. H., Waterville, Me.
9405 Mifflin, W. P., Midway, Utah.
9406 Setzler, H., Chicago, Ill.
9407 Williamson, G.E., Bridgeport, Conn.
9408 Copley, E., New York City.
9409 Glucroft, S. H., Brooklyn, N. Y.
9410 Knight, R., Boston, Mass.
9411 Wardwell, W. E., Worcester, Mass.
9412 Hench, L. W., Youngstown, O.
9413 Ferro, T. E., Bombay, India.
9414 Hagood, L., Schenectady, N. Y.
9415 McKeehan, D. C., Smuggler, Colo.
9416 Newell, F. C., Jr., New York City.
9417 Pierce, G. C., New York City.
9418 Sloane, E., San Francisco, Cal.
9419 Archer, E. T., Kansas City, Mo.
9420 Virtue, M. L., Lake Buntzen, B. C.
9421 Cameron, J. B., Chicago, Ill.
9422 de Lapotterie, H., Koppel, Pa.
9423 Petersen, E., San Francisco, Cal.
9424 Ryan, L. S., Fort Dupont, Del.
9425 Wheaton, H. A., Havana, Cuba.
9426 Scott, E. G., Boston, Mass.
9427 Thunen, E. G., Hammonton, Cal.

Total 79.

Insurance Meeting in Boston

A meeting of the Boston Section was held March 16, 1910, at which a paper by Mr. Wm. H. Blood, Jr, on "Fire Insurance from the Engineer's Standpoint" was read and discussed. Further details of this paper will be given in the May PROCEEDINGS

Sections and Branches

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS BRANCH

The second meeting of this Branch was held in Gathright Hall on February 25, 1910, with an attendance of 38 members and visitors. Mr. R. T. Shiels read the paper on "Protection of Electrical Equipment", presented by Mr. P. M. Lincoln before the Seattle Section on the occasion of his visit there last September during the Alaska-Yukon-Pacific Exposition.

UNIVERSITY OF ARKANSAS BRANCH

The University of Arkansas Branch held its regular meeting on February 17, 1910. Sixty-three members were present to hear an interesting paper by Professor Greever, of the department of English, on "The Value of English to the Engineering Student." At the conclusion of the paper Mr. Paul Mardis gave a description and exhibition of the talking arc.

At the meeting held on March 1 Mr. Ray Parcell abstracted Professor D. C. Jackson's paper on "Application of Electrical Power to Industrial Establishments". This was followed by a paper on "Illuminating Engineering", by Professor L. S. Olney, of the department of electrical engineering.

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

The regular monthly meeting of this Branch was held in Chapin Hall on February 3, 1910. The program consisted of a paper by Mr. G. E. Williams on "Interior Wiring." Mr. Williams first read architects' specifications for the wiring of a small dwelling house and a medium sized apartment building, bringing out the important features of each. He then took up wiring in detail, describing the different systems or networks, and the various methods of wiring new and old buildings. In conclusion he explained a few problems in special wiring for annunciator and burglar alarm circuits.

Atlanta Section

The members of the Atlanta Section met in the Equitable Building on February 8, 1910. It was decided to call the next meeting of the Section immediately after the Charlotte meeting of the Institute and invite some of the prominent engineers present at Charlotte to address the members of the Section while in that territory. The main subject of the meeting was a paper by Mr. A. M. Schoen representing a report to the Fulton County commissioners constituting a set of rules for the construction of high-tension and extra high-tension lines on highways in Fulton County. A number of original features in the report brought forth considerable discussion. Those taking part were, Messrs. Gordon, Peck, Wilder and Wood.

Baltimore Section

The February meeting of this Section was held in Johns Hopkins University on February 4, 1910, with 24 members in attendance. Mr. Harold C. Lomas, of the Crocker-Wheeler Company, presented a paper on "Vital Factors in the Cost of Hydroelectric Power."

Case School of Applied Science Branch

A banquet was given by the members of the Case School Branch on the evening of February 16, 1910. After an hour's social entertainment, Professor E. P. Hyde, of the National Electric Lamp Association, presented a paper on "What is Illuminating Engineering," in which he gave his audience a clear idea of the duties of an illuminating engineer. Messrs. Hoyt and Henninger, gave their views on hard knocks and soft spots of illuminating engineering.

Two meetings were held on February 23 and March 10, 1910, respectively. The program of the first meeting consisted of a review by Mr. White, on "Performances of Electric Locomotives on the New York, New Haven and Hartford Railroad."

On March 10 Mr. H. H. Woods presented a paper on "Practical Considerations of Line-Shaft and Motor-Drive of Machine Shops." Mr. M. L. Burchfield reviewed the pioneer work of the Illinois Steel Company's electric installation. Professor H. B. Dates spoke of some features in connection with the Niagara Falls power houses.

Cleveland Section

The meeting of the Cleveland Section held on February 21, 1910, was devoted to the general subject of industrial power. In the absence of Chairman Wallau, Mr. H. B. Stowe presided. Notwithstanding the inclement weather, 58 members were present to hear and discuss the four papers presented. These papers were: "Industrial Applications of the Electric Motor" by W. M. Faber; "Motors in Modern Steel Mill Practice", by R. W. Emerson; "Variable-Speed Motors", by J. C. Lincoln; "Application of Motors to. Machine Tool Drive", by M. Collens, Mr. Faber's paper dealt with motor equipment in modern steel practice and an interesting feature was his description of the United States Steel Corporation's generating plant and transmission lines, the total power in the mills being obtained from blast furnace gas used in gas engines.

Mr. Emerson described very fully the motor equipment of the Cleveland Salt Company, laying special stress on the requirements of motors that must be operated practically under salt water.

Mr. Lincoln, of the Lincoln Electric Company, . explained some theories of the designs of various types of variable-speed motors, in the construction of which he is one of the pioneers.

Mr. Collens, of the Warren Electric and Engineering Company, concluded the program with a talk on the applications of motor drive to machine tools,

and modern applications of speed control devices.

A large number of the members took part in the discussion which followed, and considerable supplemental information was brought out.

UNIVERSITY OF COLORADO BRANCH

Meetings of the University of Colorado Branch were held on February 16 and March 2, 1910. There was an attendance of 30 members at the first meeting, and 51 members at the March meeting.

At the meeting of February 16, Mr. A. L. Berg read a paper on " Bearings ". Although not electrical, the subject is of sufficient importance in connection with the design of electrical machinery to be of interest to the young engineer. Mr. Berg gave considerable data, both theoretical and experimental, relating to bearings. Mr. Faucett then read a paper on " The Manufacture of Wire." A number of appliances and methods used in the manufacture of wire were shown and explained.

At the meeting of March 2, Professor O. C. Lester, head of the department of physics of the university, presented a paper on " Atmospheric Electricity." The object of the paper was to bring out and give an idea of the cause and conditions of atmospheric electricity.

FORT WAYNE SECTION

Mr. Preston S. Millar, assistant manager of the Electrical Testing Laboratories, New York City, was the guest and speaker at the meeting of the Fort Wayne Section held on February 14, 1910, and from the viewpoint of attendance the meeting was one of the most successful the Section has ever had, 126 members and visitors being present. Mr. Millar's subject was " Recent Developments in Illuminants." The paper was illustrated by stereopticon slides, by means of which Mr. Millar was able to present tabulated statements showing the efficiencies, cost of maintenance, light-life, etc., of the various types of the most recent illuminants. The most interesting illustrations, however, were specimens of the lamps themselves, Mr. Millar having brought with him a large number of recent types, including upright and inverted gas lamps, alcohol lamps, tungsten, intensified arc lamps, and other recent electric illuminants. All of this apparatus was set up on a working basis and connected so as to be shown in actual operation. At the close of his address Mr. Millar invited inquiries from his hearers, and answered a large number in regard to the different points discussed.

On March 10, Mr. O. Cooper, engineer in charge of the switchboard department of the Fort Wayne Electric Works, presented a paper on " Three-Wire Switchboards." The paper was illustrated by a large number of diagrams and photographs. Mr. Cooper explained that his subject dealt entirely with three-wire, direct-current systems, and not with switchboards of the alternating-current, three-phase, three-wire type, and the diagrams shown were therefore limited to direct-current, three-wire switchboards. At the beginning of his paper, in order to give his hearers a summary of the three-wire systems in use, Mr. Cooper first discussed the principal systems before going into the subject of the switchboards used for controlling these systems. The paper dealt almost entirely with design, control, and the specifications issued upon the subject by consulting engineers. The consideration of costs of the different types was but briefly mentioned.

IOWA STATE COLLEGE BRANCH

The first regular meeting of the Iowa State College Branch for this year was held in the engineering assembly room on February 16, 1910. The program consisted of abstracts of three of the papers presented at Boston on February 16 under the auspices of the Institute Industrial Power Committee. Mr. E. F. Schroeder abstracted " The Applica-

bility of Electrical Power to Industrial Establishments", by D. C. Jackson. Mr. G. B. Johnson abstracted "Central Stations versus Isolated Plants for Textile Mills", by Charles T. Main, Mr. A. R. Board abstracted "The Supply of Electrical Power for Industrial Establishments from Central Stations", by R. S. Hale. The papers were discussed by Messrs. McElroy, Shane, Shuff, Meeker, Pullen and Mason.

Another meeting was held on March 2. Mr. F. J. Wettengel reviewed the paper on "Illumination for Industrial Plants," by Mr. G. H. Stickney. Two original papers were presented, as follows: "The Relative Merits of Arc and Mercury Vapor Lights", by Mr. W. T. Wells; "The Relative Merits of Moore Tube Lighting and Incandescent Lamps", by Mr. J. M. Mercer. Messrs. Shuff, Mercer, Shane, Wells, Sloan and Pullen took part in the discussion.

State University of Iowa Branch

This Branch held its regular meeting on January 10, 1910, with 20 members in attendance. Two papers were presented: "The Steam Turbine", by Mr. E. J. Aguilar, and "The Low Pressure Steam Turbine", by Mr. C. A. Kutcher. A number of candidates were admitted to membership in the Branch at this meeting.

The next regular meeting was held on February 28, 1910, the attendance at this meeting numbering 25. A number of amendments were made to the constitution, after which a paper was read by Mr. M. Luchiesch, on "Induction Generators."

Ithaca Section

The regular meeting of the Ithaca Section was held in Franklin Hall, Cornell University, on February 11, 1910, with Professor H. H. Norris in the chair, and a total attendance of 120 members. The report of the annual dinner committee was read and accepted, and the date for the dinner was set for February 25. The technical part of the program was a paper by Mr. F. H. Kroger, on "Interference in Wireless Telegraphy."

One hundred and five members attended the third annual dinner, which was given on Friday, February 25, 1910, in the assembly rooms of Sibley College. The rooms were decorated very tastefully for the occasion. The tables were arranged in a large "U" and were lighted, at the beginning of the dinner, by candles set in high-tension insulators which served the purpose of candle-holders. A miniature belt line railway encircled the speakers, and was utilized as a means for the transportation of cigars. A third-rail track was laid the whole length of the table, measuring about 150 feet, and a miniature inter-urban car made speed tests along the straight stretches. Suitable favors from several manufacturing companies were placed at each plate. At one end of the hall the Institute emblem was displayed in small electric lights of different colors. Various types of lamps, including carbon filament, tungsten, arc, and mercury vapor, were used for lighting the table. The list of speakers included Dr. E. L. Nichols, toastmaster, Professors A. W. Smith, D. S. Kimball, V. Karapetoff, and H. H. Norris, all of whom made brief addresses, while Mr. William McClellan, of New York City, delivered the principal address of the evening. A resolution was adopted that greetings be sent to Professor H. J. Ryan, now at Stanford University, Cal., the founder of the electrical engineering department at Cornell University, and a telegram was dispatched by the secretary. A vote of thanks was also extended to the dinner committee for its splendid work in arranging for the dinner.

Kansas State Agricultural College Branch

This Branch has held four meetings since December 7, 1909.

On December 7, 1909, Professor A. A.

Potter addressed the members on the subject, "Analysis of the Heat Engine from Thermodynamic and Central Station Standpoints." Mr. W. C. Lane then read Dr. C. T. Hutchinson's paper on "The Electric System of the Great Northern Railway at Cascade Tunnel."

Mr. Roy Wilkins resigned as chairman of the Branch at this meeting.

At a special meeting held on December 14, Mr. R. E. Talley was elected chairman to succeed Mr. Wilkins. Other business matters of minor importance were transacted.

The next regular meeting was held on January 18, 1910. Mr. Truskett discussed the paper by Mr. H. L. Doherty on "Development and Operation of Hydroelectric Plants." Mr. George Thatcher presented a paper on "Theatre Illumination." Mr. R. E. Talley discussed the possibilities of electricity on the farm.

On February 1, 1910, the Branch was addressed by Mr. J. L. Buchanan, of Chicago, on "Transformer Characteristics." Mr. H. T. Morris reviewed Dr. W. S. Franklin's paper on "Space Economy of the Single-Phase Series Motor."

University of Kansas Branch

The regular meeting of this Branch took place on February 9, 1910, in Blake Hall. There were present 29 members and visitors. The speakers of the evening were Professor George C. Shaad, head of the electrical engineering school, and Assistant Professor C. A. Johnson. Professor Johnson spoke on "The Advantages of a Course in the Testing Department of the Westinghouse Electric and Manufacturing Company." He described in detail the experience to be gained by a student taking this course. Professor Shaad spoke on "The Advantage to the Technical Graduate of a Course in the Testing Department of the General Electric Company." He showed how the testing work was carried on, and told of the opportunities for the student after completing the course. The talks were of especial interest to the senior electrical students. Mr. F. C. Lynch gave a report of current engineering events.

Lehigh University Branch

The March meeting of the Lehigh University Branch was held in the physical laboratory on March 8, 1910, with 73 members in attendance.

After a brief business session, Mr. R. B. Swope read a paper on "The Acceleration of Cars and Trains." Mr. Swope explained various devices which can be placed on cars in operation, in order to determine their acceleration in starting.

Mr. R. P. Heller spoke on "Heating Systems." He described the principal types of steam and water systems now in use in large office buildings in New York City.

The last speaker, Mr. R. P. Stevens, president of the Lehigh Valley Traction Company, gave an address on "The Business or Executive Side of Electrical Engineering." Mr. Stevens stated that two problems confronting electric railway managers are, how to get good college men to fill responsible positions, and how to obtain sufficient capital to execute plans of development. The importance of a good organization in any company is recognized, and upon this depends largely the success of an undertaking. Mr. Stevens then discussed plans for the promotion of traffic, and methods of reducing operating expenses. In conclusion he outlined the attitude of his company toward its employees, and the relation of a public service corporation to the municipality.

Lewis Institute Branch

A large audience assembled at the Lewis Institute at the meeting of the Branch held on February 23, 1910, to hear a lecture by Mr. M. L. Johnson, engineer with the Automatic Electric Company of Chicago, on "Manual and

Automatic Telephones." The lecture was illustrated by drawings and apparatus. Mr. Johnson explained the method of operation of the manual boards in Chicago, showing the circuits and instruments involved in making a single call from one exchange to another. He then traced the same call through the automatic board and made a comparison showing the advantages of the automatic system. The simplicity of operating exchanges with the automatic system was fully explained. The attendance numbered 275 members and visitors.

Los Angeles Section

Three meetings have been held by the Los Angeles Section since that of November 23, 1909, the last one reported in the Proceedings.

On December 28, 1909, the members were addressed by Mr. H. R. Noack, on " Aging of Insulators." The paper was discussed by Messrs. O. H. Ensign, E. F. Scattergood, E. K. Davis, E. R. Northmore, and J. A. Lighthipe.

The next meeting was held on January 25, 1910. Mr. C. W. Koiner presented a paper on " Some Features of Modern Street Illumination ", which was accompanied by lantern slides and exhibits. Those taking part in the discussion were, Messrs. R. H. Manahan, A. Kennedy, E. R. Northmore, J. A. Lighthipe, A. S. Glasgow, and H. Wiatt.

At the meeting of February 25, 1910, Mr. R. W. Shoemaker read a paper on " Electrical Mine Engineering ", which was discussed by Messrs. C. A. Copeland, R. H. Manahan, J. A. Lighthipe, and V. L. Benedict. Mr. L. Keller abstracted and discussed Mr. W. Lee Campbell's paper on " Modern Automatic Telephone Apparatus, after which the meeting adjourned to inspect the Hill Street automatic exchange of the Home Telephone and Telegraph Company.

Madison Section

The Madison Section held its second meeting of the year on March 1, 1910. Forty members were present, and Chairman M. H. Collbohm presided. Mr. M. D. Cooper, of the engineering department of the National Electric Light Association, Cleveland, Ohio, spoke on " The Tungsten Lamp."

University of Maine Branch

The University of Maine Branch, which for over a year has been inactive, was reorganized on February 16, 1910, and the following officers elected: Chairman, A. T. Child; vice-chairman, H. W. Vickery; secretary, J. P. King; treasurer, N. C. Cummings; Executive Committee, A. T. Childs, J. N. Eaton, L. M. Gerrish, A. S. Moore, I. M. Stover. At this meeting a constitution was submitted to the executive committee and adopted.

University of Michigan Branch

The University of Michigan Branch has held six meetings this season, as follows:

October 15, 1909. At this meeting officers were elected for the ensuing year. Those elected were: Chairman, E. B. McKinney; secretary, G. J. Wagner. Membership and program committees were appointed.

October 27, 1909. Mr. G. J. Wagner presented a paper on " Street Railway Track Bonding."

November 17, 1909. A committee was appointed to formulate a constitution and by-laws. A paper was read by Mr. R. K. Holland on " Electrification in the Navy."

December 16, 1909. A constitution and by-laws were submitted by the committee appointed at the previous meeting, which were accepted and adopted. The members were addressed by Mr. F. S. Mather.

January 26, 1910. This was a business meeting. It was decided to make a formal announcement of the aim and object of the Branch. Mr. R. K.

McMaster was delegated to arrange for catalogues for members.

February 23, 1910. At this meeting Mr. Whitmore read a paper on "The Fish Street Power Station of Chicago."

There was an average attendance of 18 members at these meetings.

University of Missouri Branch

The members of the University of Missouri Branch met on January 10, 1910, to discuss the "Columbia Municipal Water and Light Plant." The subject was again taken up at the meeting of January 24. An abstract of the discussion is printed elsewhere in this issue.

At the meeting of February 14 the educational papers of Dean Schneider, Dr. Steinmetz, and Charles F. Scott were reviewed and discussed. Those taking part in the discussion were, Dr. W. W. Charters, Professor H. Wade Hibbard, and Mr. J. A. Whitlow. The papers were reviewed by Messrs. C. S. Lankford, T. S. Haddaway, and N. C. Mann.

University of Nebraska Branch

The fourth meeting of the University of Nebraska Branch was held on February 8, 1910. At the invitation of Mr. W. C. Shinn, 27 members visited and inspected the W. C. Shinn Lightning-Rod and Cable Company's factory. A staff of employees were at work during the evening. Every facility was afforded the members to become acquainted with the special types of cable making machinery employed, and the products and processes of manufacture.

New Hampshire College Branch

Instead of the regular meeting of the Branch, the members attended a lecture given by Mr. Hiram N. Savage, on "Irrigation Problems in the West." Mr. Savage is an alumnus of the New Hampshire College, and for a number of years past has been a division engineer in the United States Reclamation Service. He described the construction of a number of recent irrigation projects, illustrating the more important features by means of lantern slides. The methods of handling the various problems arising in the course of the work were explained. Considerable discussion followed the lecture. About 60 members and visitors were present.

Ohio State University Branch

Meetings were held by this Branch on February 24 and March 3, 1910. Mr. R. H. Marriott, president of the Wireless Institute, of New York City, was the speaker at the meeting of February 24, and presented a paper on "Wireless Communication."

At the meeting of March 3 Mr. Teegarden read a paper on "City Telephone Lines." The date of the electrical show to be given in conjunction with the mechanical engineers was changed to April 15.

Oregon Agricultural College Branch

The third of the series of papers on electrochemistry was presented before the Oregon Agricultural College Branch on February 28, 1910, by Messrs. F. E. Ewart and F. J. Williams. The subject discussed was "Electroplating." Mr. Ewart treated it from a historical standpoint, while Mr. Williams took it up from the practical side. Mr. J. K. Fairchild then reviewed Mr. W. Lee Campbell's paper on "Modern Automatic Telephone Apparatus", which he supplemented with many facts gained through personal experience with the automatic systems of Portland and San Francisco. Nearly all of the 30 members present took part in the discussion.

Pennsylvania State College Branch

On February 2, 1910, forty-five members of this Branch were addressed by Professor J. P. Jackson, dean of the school of engineering. Professor Jackson's subject was "Lighting."

At the meeting held on February 9,

Dr. A. S. McAllister, of New York City, delivered a lecture on the subject of "Lightning." Dr. McAllister described the phenomena accompanying lightning discharges, and the method of protection from such discharges. Considerable attention was given to various types of lightning-arresters.

Philadelphia Section

Owing to the opening of the Philadelphia Electrical Show on February 14, 1910, the regular monthly meeting of the Philadelphia Section was postponed to February 21. The papers presented were: "Methods of Recording Telephone Calls", by C. W. Sharer; "Measurement of High Insulation Resistance", by A. J. Rowland. The papers were discussed by Messrs. Hering, Hoadley and Rowland.

Pittsburgh Section

One hundred and twenty members of the Pittsburgh Section met in the Carnegie Institute, Pittsburgh, Pa., on February 8, 1910. A paper on "Cost of Transformer Losses" was presented by Mr. Ralph W. Atkinson.

At the meeting of the Section on March 8, Mr. B. P. Rowe gave a talk on "Some Practical Hints for Procuring a Satisfactory Switchboard." Mr. Rowe discussed the subject from the purchaser's standpoint, showing that the question of what apparatus is needed, and what particular type, are the first considerations, after which its arrangement and assembly should follow. He spoke in favor of keeping as much apparatus off the back of the switchboard as possible. In discussing the paper Messrs. H. L. Fullerton and H. N. Muller offered some points from their own experience, and Mr. J. S. Jenks referred to the difficulty of building an ideal switchboard in an old structure. One particular feature mentioned in the discussion was distant control by bell crank and by transmission rope.

Pittsfield Section

Dr. W. S. Franklin, of Lehigh University, was the guest of the Pittsfield Section at its meeting held in the Wendell Hotel on March 10, 1910, and addressed the 180 members present on "The Gyroscope and Its Recent Applications."

Portland Section

A discussion of the general subject of industrial power was resumed by the members of the Portland Section at their regular meeting on February 15, 1910. Thirty-five members attended. The following papers on various phases of the subject were presented: "Electric Drive in Car Shops", by J. J. Brady; "Electrically Driven Printing Presses", A. W. Cochran; "Gold Dredging", R. F. Monges; "Conditions of Motor Application on Large Lighting Systems", H. R. Wakeman; "Electrical Installation for Mining Plants", L. B. Wickersham.

Purdue University Branch

On Tuesday evening, January 11, 1910, Messrs. G. T. Dunklin and R. B. Howland addressed the members of the Purdue University Branch on the subject of "Power Development at Niagara Falls. During the Christmas vacation Messrs. Dunklin and Howland visited the plants of the Ontario Power Company and the Niagara Falls Power Company. The discussion was illustrated with views of the machinery installed at Niagara, and the control and distributing apparatus. Seventy-five members attended the meeting.

Professor C. F. Harding addressed the Branch on the evening of February 8, on "The Equipment of the New Purdue Shops and the Generation and Distribution of Electric Power." A summary of his remarks is as follows:

"The problem of equipping these shops with light and power is not a special case of engineering. Owing to the educational features it cannot be solved in the same manner as in the

case of an industrial plant; yet, it is a typical problem in engineering. In the shops of the new engineering building the machines are in some cases to be grouped, while others are to have individual drive. There will be four overhead shafts in the east end of the new machine shops, and two in the west end. Each of these shafts will be driven by a constant speed motor mounted overhead. Machines requiring a variation of speed will be driven by individual motors of the direct-current type. The blowers in the forge and foundry will have individual motors. In the wood room some machines will be grouped as in the machine shop, but in this case the motors will be mounted on the basement ceiling. Besides these there will be several motors for ventilation purposes, and also several small ones of variable speed in the lecture rooms for demonstration purposes. The lighting of the building amounts to 57 kw. The wiring for lights is to be laid out by the architects so it does not enter into the problem.

The next question after having determined the number and location of the motors is the kind which are to be used. Alternating-current motors will be used for constant drives, and direct-current motors will be necessary for variable speeds; hence, the building will be wired for both 220-volt alternating-current, and 220-volt direct-current motors. To decide between the two or three-phase alternating-current motors was a very difficult problem. Since, however, the three-phase system required only .75 of the amount of copper, and it was easier to install, this was chosen. Then came the question of wiring. The choice lay between the radial system and the main system. The first cost of the radial system is high. Future installations may easily be provided for. The system of wiring mains and tapping off to the motor is cheaper in first cost, but unless a careful calculation is made it will be difficult to provide for future installation. The committee finally decided upon the latter system. In the machine shop two mains of three wires each will be placed for both alternating and direct current. The same method will be used in the wood shop. The motors of the forge room will be provided for in the machine shop installation. The motors used throughout the shop range from three to 20 h.p. The problem with which the committee had to deal included the remodelling of the present campus distribution system, as well as that of the new building. The radial system is now employed, but as this must be remodelled on account of the size of some of the wiring, the committee decided that the power and light should be distributed by two three-phase mains; one running north and south, and the other east and west. To supply the increased demand for power it has been thought best to install a new 250-kw. unit at the power plant, and to supply the old unit with a transformer, so that it may be used as a relay. Whether the new generator is to be driven by a turbine or reciprocating engine has not yet been definitely decided, but the conditions seem to favor the latter.

A paper on "Use of Electricity in the U. S. Navy" was read at the meeting held on February 15, 1910. The speaker was Mr. C. S. Beardsley. An abstract of Mr. Beardsley's paper follows:

"On most of the battleships electricity is generated by four 80-volt, 50-kw. generators directly connected to vertical engines. The generators are arranged in pairs, and are placed forward, two on a side. There is one switchboard of four panels so arranged that power may be supplied from any one of these generators for the operation of motors, lights and signals of all kinds. The new ships are supplied by the standard 110-volt generators, but on the battleship Texas and all the older ships the standard was made 80 volts. The generator units are mounted so that the gyroscopic effects are as small as possible. Motors are used for closing

the doors to the water-tight compartments, the doors to the magazine, and those on the elevator of the ammunition hoist. Fans are operated in the officers' quarters. Signals are transmitted by various arrangements of colored incandescent lamps, the wigwag system, and by wireless methods. An intercommunicating telephone system and an arrangement of lamps serve for signaling about the ship.

The wiring of the ship is unique. A very high insulation resistance is necessary, and for this reason sealed pipes must be run. Salt water is very destructive to insulation. Junction boxes are situated every 15 or 20 feet, thus simplifying the locating of troubles. The intercommunicating telephone system is so wired that only from two telephones can the captain be called, although from his own he can communicate with all of the telephones. Orders are sent to the gun crews by means of a visible order being lighted in the gun room by closing a sufficient e.m.f. through an incandescent lamp mounted behind the signal. The wireless antenna is mounted from the top of the main mast to the top of the flag mast, great care being taken in the insulation. The telegraph quarters are in a very small room just below the flag mast. Guns and mines are fired by electric sparks.

Rensselaer Polytechnic Institute Branch

The third meeting of this Branch since its organization was held on February 25, 1910, with an attendance of 57. Mr. W. Lee Campbell's paper on "Modern Automatic Telephone Apparatus" was reviewed by Mr. W. J. Williams, after which there was a discussion of the wireless telegraph apparatus recently purchased by the Rensselaer Polytechnic Institute.

St. Louis Section

Two hundred and fifty members and their friends gathered at a meeting of the St. Louis Section in the Soldan High School on February 9, 1910, to hear addresses by Mr. H. C. Toensfeldt, structural engineer of the St. Louis Board of Education, and Mr. C. A. Bulkeley, chief engineer. Mr. Toensfeldt's paper, which was illustrated by lantern slides, described the structural and architectural features of the new Soldan High School. Mr. Bulkeley described the mechanical and electrical equipment of the building. After the addresses, the efficiency of the ventilating system was demonstrated by a smoke test, and the building was then thrown open for the inspection of those present. The school has its own power plant, the three-wire system of distribution being used throughout, and is lighted by tungsten lamps with holophane reflectors. The auditorium is lighted by means of large holophane hemispheres using tungsten lamps. The members of the Section are indebted to the St. Louis Board of Education for arranging this interesting meeting.

San Francisco Section

The regular meeting of this Section took place on February 25, 1910, in the Home Telephone Company Building. Professor Cory, of the University of California, read a paper entitled, "The Public Service Corporation." Professor Cory's wide experience, not only in engineering lines, but as a consulting expert to corporations and municipalities as well, has given him a broad insight into the many problems in connection with municipalities and public service corporations, and the meeting was one of the most successful held by the San Francisco Section.

Schenectady Section

Mr. W. H. Pratt, of West Lynn, Mass., was the principal speaker at the eighth meeting of the Schenectady Section, held on February 15, 1910. The subject of Mr. Pratt's lecture was "The Wattmeter." He gave a brief outline of ampere-hour and watt-hour meters used in the past and at present in this coun-

try and abroad. From the well-known direct-current recording wattmeter, operating on the motor principle, the speaker passed to the induction type of alternating-current meter, explaining thoroughly the technical principles of its operating, the effects of varying voltages, frequency changes, and wave-form variations. Mr. Pratt's long engineering experience in this field enabled him to present the subject in a very clear and thorough manner, and the meeting was a most successful one. About 200 members attended the meeting.

There was another large gathering at the ninth meeting of the Section, held on March 1, at which a lecture was delivered by Mr. Henry G. Chatain, on "Applications of Gas Engines." Mr. Chatain gave a detailed description of gas engines of from one to 16 cylinders, and their applications to automobiles, stationary machines, traction equipment, and flying machines. One of the most interesting features of the lecture was a description of the multi-cylinder engine of high power and light weight as used on aeroplanes. Lantern slides of the machines of Wright, Curtis and other prominent aviators were shown to illustrate this engine. Mr. A. W. Jones took up the subject of self-propelled gasolene electric cars on branch steam roads, showing that such cars are not only practical, but greatly needed by the public. Mr. J. M. Matthews gave a description of a recently developed device known as the dynatax, and its possibilities in connection with gas engines as applied to automobiles and flying machines.

Seattle Section

At the regular meeting of the Seattle Section, on February 19, 1910, Mr. John Harisberger, of the Seattle-Tacoma Power Company, presented a series of stereopticon views illustrating his experiences during the earlier days of electrical development on the Pacific coast. Of especial interest were a number showing long-distance transmission at high frequency in Portland, Oregon. As most of the members of the Seattle Section are connected with the various power companies considerable discussion followed, in which points of interest were brought out. At the next meeting a paper will be presented by Mr. Stevens, on "Gas Engine and Electrical Equipment at Gary, Indiana."

Stanford University Branch

Professor S. B. Charters paper "Reduction in Capacity of Polyphase Motors, Due to Unbalancing in Voltage" read at the Frontenac Convention, was reviewed and discussed by the members of the Stanford University Branch at a meeting held on January 18, 1910.

The meeting of February 8 was given over to a discussion of a test on the Great Northern Power Company's Oakland steam plant.

Syracuse University Branch

On February 10 the regular monthly meeting of this Branch was held in the university, with a total attendance of 16 members. Mr. George Goldman presented an abstract of Dr. C. T. Hutchinson's paper, "The Electric System of the Great Northern Railway Company at Cascade Tunnel."

At the meeting of March 10 Professor A. R. Acheson reviewed and discussed the paper by Mr. H. L. Doherty, on "Development and Operation of Hydroelectric Plants."

University of Texas Branch

Two meetings of this Branch were held in February. On February 11 Mr. E. B. Barnett read a paper on "Parallel Operation of Alternators." On February 25 a paper was presented by Mr. W. W. Holden, on "Strength of Wrought Iron." Mr. C. G. Smith reviewed the Institute paper on "The Purchase of Fuel on a British Thermal Unit Basis."

Toledo Section

At the regular monthly meeting of the Toledo Section, held on March 3, 1910 in the Y. M. C. A. auditorium, Mr. J. B. Sando, of the hydraulic engineering department of Allis-Chalmers Company, read a paper on "High Pressure Fire Service for Cities." Mr. Sando described thoroughly many high pressure fire service installations of various types in American cities. He dealt specifically with the installations in San Francisco, Spokane, Baltimore, Philadelphia, Coney Island, New York City, and Rhinelander, Wis. After the reading of the paper, lantern slides were used to show the installations, the results obtained from such equipment, and details of construction of the various types of apparatus. Invitations sent out to city officials were responded to to some extent. The subject is one of special importance in Toledo at this time, as a high pressure service district has been laid out, though the location of the station has not yet been determined upon.

Urbana Section

The Urbana Section held its regular meeting on February 23, 1910. Messrs. H. C. Kendall and E. J. Berg were elected members of the executive committee. Secretary J. M. Bryant made a brief address on the work and scope of the Institute and explained the conditions for membership. Dr. C. T. Hutchinson's paper on "The Electric System of the Great Northern Railway at Cascade Tunnel" was then abstracted by Mr. Kendall. Mr. Kendall spoke of the advantages and disadvantages of the use of electricity on the main lines of large railways, and commented on the special features of the system at Cascade Tunnel.

In discussing the paper, Dean W. F. M. Goss took the view that the steam locomotive is still far from being replaced by the electric locomotive. He said in part: "There are many significant points brought out by this paper. First: The tremendous increase of power for locomotion in the case of the electric locomotive. The steam locomotive has to carry its own power plant as well as its motors, and hence the amount of power per ton weight must be less than for the same weight of electric locomotive. Secondly: The low frictional resistance of the electric locomotive. The values given in the paper show a wide range in the frictional differences in the ordinary steam locomotive. In some tests on an Atlantic type of locomotive made some time ago, using first grease, then oil, for lubricant, I find a difference of 1,000 lb. pull at the draw-bar between the two lubricants. This together with the compression losses of the steam locomotive would make it inferior to the electrical equipment. With large locomotives there would be a still greater difference between the two. Thirdly: I do not consider the fuel data as given in the paper very reliable. I do not believe there is much difference between the two cases. Along other lines the paper is naturally suggestive, and indicates possibilities in this direction in the future."

The paper was further discussed by Dr. C. T. Knipp and Mr. J. M. Bryant, and questions brought out in the discussion were replied to by Mr. Kendall. Other points brought out in connection with the paper were: type of catenary construction, complications introduced by two trolleys, and the consequent cross-overs, and the disadvantages for a higher speed service than that obtained in this system. Where the maximum speed of operation is but 15 miles per hour, very little trouble is experienced from trolleys getting off the wire.

Washington Section

The regular monthly meeting of the Washington Section was held in the George Washington University on February 8, 1910. A paper on "Electric Heating and Its Applications" was read by Mr. W. H. Rue.

At the next regular meeting, held on March 9, a paper was read by

Mr. L. E. Barringer, on "Insulating Materials." Mr. Barringer spoke at length on the various substances used in the manufacture of insulation, and the particular condition which each substance was fitted to meet. A large number of samples were shown, illustrating not only the different materials, but also the various stages in the process of manufacture.

Washington University Branch

At a meeting of this Branch held in Cupples Hall II on February 14, 1910, the members were given an insight into the operation of a large central station. Mr. Vennum, of the mechanical department of the Union Electric Light and Power Company, gave a talk on "The Ashley Street Plant." A detailed explanation was given, illustrated by photographs, of the process of converting energy in the form of coal into electricity. The coal is hoisted from the cars to the top of the bunkers, about 100 feet, in a two-ton shell bucket, at the rate of three trips per minute. The bunkers, which have a capacity of 12,000 tons, are located immediately above the boiler-room, and the coal is fed by gravity to the boilers below. There are 68 boilers in the Ashley Street plant—40 water-tube, and 28 internally fired marine boilers—with a total rating of 38,000 h.p. The marine boilers are now being replaced by water-tube boilers, which have proved more satisfactory. The water in the boilers is purified in the same manner as that at the St. Louis water works; namely, the dirty river water is treated with lime, iron and soda, and then discharged into settling basins operating in series. The capacity of this system is about 150,000 cubic feet per day. The ashes are discharged directly into hoppers which are emptied into cars from the floor below. These are hoisted on an electric elevator to the top of the ash-dump. The electrical equipment consists of two 1,500-kw. and three 3,000-kw. engine-driven generators, two 2,000-kw., three 5,000-kw., and one 12,000-kw. steam-turbine-driven generators. The steam of the turbines is returned and used again, while the engine exhaust is not used again, as it contains too much oil. The water for the condensers is pumped by two centrifugal pumps, steam-driven, with a capacity of 70,000,000 gallons in 24 hours. At the conclusion of the talk arrangements were made for a tour of inspection of the plant for the following day.

Worcester Polytechnic Institute Branch

A meeting of the Worcester Polytechnic Institute Branch was held on February 25, 1910, in the lecture room of the engineering building. Mr. C. H. Tower presented a paper on "High-Tension Phenomena." Mr. Tower described various features in the design of transformer connections and terminals which he illustrated by means of sketches. He also gave his attention to the different types of transformer terminals in use for high-tension work at the present time, explaining the theoretical reasons for the design of the condenser type.

The Branch was addressed on the evening of March 11 by Mr. John Stone Stone, of Boston, who spoke on "The Evolution of Modern Wireless Telegraphy," before an audience of 68 members. Beginning with the original Hertz apparatus, consisting of a dumb-bell interrupter and a simple loop receiving circuit, Mr. Stone traced the development of wireless apparatus to the Marconi improvement of making the earth serve as one-half of the Hertz transmitter, and the later modifications which have made wireless telegraphy a commercial success. In speaking of this development, Mr. Stone explained several features which he personally had worked out; particularly an additional circuit in the receiving apparatus so connected as to eliminate stray currents such as atmospheric or static waves, which have a bad effect on the receiving station. The subject

was illustrated by sketches showing the wiring in the elementary forms of wireless apparatus and the reasons for inefficiency of the earlier types.

Columbia, (Mo.) Municipal Water and Light Plant.

The municipal water and light plant at Columbia, Mo., was the topic of discussion at a meeting of the University of Missouri Branch on January 10, 1910. The following phases of the subject were presented and discussed: "Financial History," by Professor L. M. Defoe; "Water Supply," by Professor T. J. Rodhouse; "Load Factor," by Mr. K. A. McVey.

Professor Defoe stated that two of the principal reasons why the public became dissatisfied with the private company which supplied the city with water and light from 1892 to 1904 were impure water from a muddy creek, and the closing down of the electric light plant at midnight. These proved strong factors in the special election held to decide the question of municipal ownership. The election resulted in the purchase of the company's property and rights, and a bond issue of $100,000 was authorized, of which $67,506.72 was paid to the company for the property. A board of public works was then appointed by the Council. The next step was the removal of the plant to a new site and deep wells were sunk for a pure water supply. Included in the purchase was also the company's electric light plant. This was moved to a site near the wells. Subsequent bond issues for extensions were necessary and the bonded indebtedness was thus increased to $140,000. Provision was made for a sinking fund and the payment of interest by a special tax. This has reduced the city's debt by $30,000, and established a sinking fund of $15,000, leaving the actual amount of indebtedness $95,000. By means of this special tax about $12,000 are raised annually, which will enable the city to retire the bonds before the 20-year period. The city formerly paid the private company $8,000 per annum for the service rendered to the city by the company. The value of the service under municipal administration is equivalent now to over $12,000 annually. As the population has doubled during the period from 1904 to 1909, the present service is inadequate, and changes or improvements have become necessary. Professor H. B. Shaw has been retained to report on the present conditions and the extent and cost of the required improvements. The plant equipment consists of four boilers, three being rather old, having a total capacity of 850 h.p., and three engine and generator sets with a total rating of 575 kw., two air compressors for deep well pumping, and four service pumps. The annual income for electric service is about $37,000; from water supply $13,000, and from other sources about $8,000; making a total income of $58,000.

Professor Rodhouse presented a tabulated statement of the equipment and general features of the water works. Complete information regarding the water supply, however, was not available, in the absence of Professor Shaw's formal report to the City Council. Professor Rodhouse pointed out that air-lift pumping gave low efficiencies—15 to 40 per cent—and that compressor efficiencies were often between 60 and 70 per cent. Another point brought out was that the steam consumption of compressors was high, and that there were unusually large water losses in city distributing systems.

Mr. McVey presented data in regard to the lighting plant. There are in use for street lighting in Columbia 177-40 c-p. incandescent lamps arranged in two circuits of No. 8 B. and S. wire, each circuit controlled by a 6.6 ampere regulator, and 31 arc lamps supplied by a 7.1 ampere, 50-light tub transformer. There are 235 service transformers, 2,200 to 110 volts, a few being used for three-phase motor service at 220 volts or 440 volts. There are installed 1,000 customers meters. A

load curve taken in December, the period of heaviest load, gave 2,500 kw. hours per day. and a peak load of about 315 kw., making a daily load factor of about 18 per cent., based on rated capacity, and about 33 per cent. based on maximum load.

The discussion of the Columbia water and light plant was resumed at the meeting of the Branch held on January 24, 1910. The speakers and subjects were: Mr. L. V. Seares, "Series Incandescent Street Lighting;" Mr. J. D. Bowles, "Present Performance at Plant;" Mr. R. A. Beekman, "Losses in Transmission System."

Mr. Sears gave the following description of the incandescent street lighting system. The system consists of:

2-15-kw., 6.6-ampere regulators.
1 two-circuit panel,
2 lightning arresters,
175 series incandescent lamps of 40 c-p., 140 watts, 6.6 amperes,
17 miles of No. 8 B. and S. copper wire

A comparison of this system with one using tungsten lamps is tabulated below.:

	Type of lamp	
	Carbon	Tungsten
Average mean horizontal candle-power	40	40
Watts per c-p	3.5	1 to 1.25
Average life in hours	1,000	1,350
Kw. hours during life	140	67.5
List price of lamp	$.49	$1.50
Cost of renewals annually (4,000 hours use)	$1.96	$4.44
Kw. hours annually (4,000 hours use)	560	270
Cost of energy annually at $.0125 per kw. hour (4,000 hours use)	$7.00	$3.37
Total running cost per lamp per year	$8.96	$7.81
Annual reduction in running cost (175 lamps) 4000 hours use		$201.50
Additional investment required		176.75
Interest at 8 per cent on additional investment		14.00
Annual net saving (175 lamps) 4000 hours use		187.50
Cost of renewals per lamp annually (2,180 hours use)	$1.07	$2.42
Cost of energy per lamp annually (2,180 hours use)	3.82	1.84
Total running cost per lamp per year 2180 hours use	4.89	4.26
Annual reduction in running cost (175 lamps) 2180 hours use		110.00
Additional investment required		176.75
Interest at 8 per cent on additional investment		14.00
Annual net saving (175 lamps) 2180 hours use		96.00

In the above figures the low price of $.0125 per kw.-hr. was taken because only the variable or fuel cost of power was considered.

In the general discussion the following points were brought out. The life of tungsten lamps may be somewhat higher than 1,350 hours, and as high as 1,500 hours. During windstorms it has been found that lighting the lamps tends to prevent breakage. Lightning seems to be a frequent cause of breakage, and to cause more damage in incandescent circuits than in arc circuits.

Mr. J. D. Bowles showed by means of a load curve that the highest load, 305 kw., is at 7 p.m., and the smallest, 15 kw., occurs between 8 a.m. and 2 p.m. The largest unit, consisting of a high-speed Wisconsin Corliss engine connected to a 250-kw., 2,300-volt, 60-cycle alternator, is used during the six-hour period of heaviest load, supplemented by a 200-kw. inductor alternator. There are two separate load circuits, and the machines are operated separately on these circuits. Parallel operation is never attempted. During the 18 hours of light load the two circuits are both connected to a 125-kw. alternator. The switchboard is not equipped with wattmeters or power-factor meters. The plant is equipped with two air compressors for the wells. These compressors are operated at considerable excess of pressure on both steam and air ends, and are giving poor economy. The increase in operating pressure also results in continual trouble with the standard pipe fittings, and leakage. Steam frequently fills the room. The boilers act as if over-

loaded and the firemen have difficulty in keeping up steam. The steam pipes are not covered, and there are no sectional valves for isolating different parts of the plant.

Mr. Beckman, in discussing transmission losses, stated that meter losses varied between 3 and 15 watts each. With 1,000 meters connected, and an assumed cost of two cents per kw-hr. there would be a minimum annual loss in the meters of $525.00, an average loss of $1,575.00, and a maximum cost of $2,625.00. In the 17 miles of street lighting circuit there would be, at two cents per kw-hr., an annual loss of $192.00, and in the approximately 14 miles of street arc lighting circuit, an annual loss of $160.00. In the line between the station and the city, approximately one and a quarter miles long there would be an annual loss of $2,000.

Personal

Mr. H. T. Eddy recently opened a large garage at 2108 May Street, Walnut Hills, Cincinnati, Ohio.

Mr. W. Chappell has accepted a position with the Western Canada Power Company, at Vancouver, B. C.

Mr. Carl Bendeke has left the New York Edison Company, and is now with the Ontario Power Company, Niagara Falls.

Mr. Miles V. Stewart has been appointed chief engineer of the Mexican General Electric Company, City of Mexico.

Mr. B. A. Behrend has been elected a foreign member of the Council of the Electrotechnischer Verein of Berlin, Germany.

Mr. L. H. Conklin has left the Scranton Electric Company to enter the operating department of J. G. White and Company.

Mr. Leroy B. Cramer, secretary of the Portland Section, was married on February 9, 1910, to Miss Carrie Della Seal, of Portland, Ore.

Mr. Charles E. Waddell announces having established offices for a general engineering practice at 78 Patton Avenue, Asheville, N. C.

Mr. J. M. Fried, formerly with the General Electric Company, is now associated with the Poughkeepsie Light, Heat and Power Company, of Poughkeepsie, N. Y.

Mr. G. M. Soxman was on October 1, 1909 appointed superintendent of equipment of the Southwestern Telephone and Telegraph Company, Dallas, Texas.

Mr. Robert N. Davidson has left the Salt Lake and Ogden Railway Company, and is now chief electrician for the Central Coal and Coke Company, Rock Springs, Wyo.

Mr. W. H. Kempton having resigned as electrical engineer for the Johns Pratt Company, has accepted a similar position with the Ohio Brass Company, of Mansfield, Ohio.

Mr. A. B. McIntyre, of the General Electric Company, Schenectady, was recently transferred to the transformer engineering department of the company's Pittsfield works.

Mr. John Boettner, Jr., has withdrawn from the Isthmian Canal Commission at Panama, to go with the Westinghouse Electric and Manufacturing Company, St. Louis office, as salesman.

Mr. Claude A. Bulkeley, has become associated with the firm of Marks and Woodwell, consulting engineers, of St. Louis, Mo. Mr. Bulkeley was formerly with the St. Louis Board of Education.

Mr. H. C. Hall, until recently in the lighting department of the General Electric Company, Schenectady, has been transferred to the same department in the New York offices, 30 Church Street.

Mr. Selby Haar recently was transferred from the alternating current engineering department to the power and mining engineering department of the General Electric Company, Schenectady N. Y.

Mr. A. E. Silver, formerly electrical engineer with the Carolina Power and Light Company, has resigned to join the engineering staff of the Electric Bond and Share Company, of New York City.

Mr. Val J. Crowley, formerly with the Oroville Water, Light and Power Company, has resigned to take charge of the substation erection work of the Sacramento Valley Power Company, Redding, Cal.

Mr. J. V. Anderson has resigned from the Colorado Springs and Cripple Creek District Railway Company to become electrical engineer for the Ernestine Mining Company, of Mogollon, New Mexico.

Mr. R. L. Lunt has resigned from the engineering department of the Electric Storage Battery Company to become electrical engineer for the Electric Carriage and Battery Company, of Minneapolis, Minn.

Mr. Fred B. Wright resigned in January his position as instructor of electrical engineering in the University of Vermont, and is now connected with the Western Electric Company, in the New York office.

Mr. H. M. Myers, of the General Electric Company, has been transferred from Schenectady to the power and mining engineering department of the Boston works, 84 State Street, Boston, as small motor engineer.

Mr. E. N. Goodman has removed to Cincinnati, Ohio, where he has been appointed district sales manager of the The Electro-Dynamic Company. Mr. Goodman was formerly with the Sprague Electric Company, New York City.

Mr. Franklin P. Wood formerly superintendent of the Black Hills Traction Company, Deadwood, S. D., has taken the management of the Colorado Railway, Light and Power Company, Trinidad, Colo.

Mr. O. H. West has been placed in charge of the construction of a 20,000-kw. station for the Indiana Steel Company at Gary, Ind. Mr. West formerly was division electrician for the Indiana Union Traction Company, Anderson, Ind.

Mr. Lyman P. Hammond, for the last five years with the Denver Engineering Works Company, has resigned his position as secretary and sales manager to become manager of the sales department of the Central Colorado Power Company.

Mr. Edgar Strasburger, of the cable department of the Western Electric Company, New York City, has been transferred to London, where he will have charge of the company's cable manufacturing plant at the North Woolwich works.

Mr. H. H. Van Staagen has been transferred from the Philadelphia office of the Westinghouse Electric and Manufacturing Company, where he had charge of the detail and supply sales, to the Boston office of the same company.

Mr. Robert C. House, until recently in the sales department of the Safety Insulated Wire and Cable Company, has joined the motor and generator sales department of the Sprague Elec-

tric Company, and is located in the New York office.

MR. J. M. HOLLISTER, electrical engineer, who for 15 years has been with the Western Electric Company, Chicago, resigned on January 1 to accept a position in the power and mining commercial department of the General Eectric Company at Schenectady.

MR. C. AUSTIN GREENIDGE has resigned as general manager of the electric department of the Utica Gas and Electric Company, a position which he has held for eight years, and is now connected with J. G. White and Company, of New York City.

MR. EDWIN B. THORNTON having completed the work of installing a power plant for the Continental Copper Mining and Smelting Company in its mines near Hill City, S. D., has removed to Chicago to enter the employ of the Chicago Sanitary District.

MR. R. H. FORD, who for the last year has been electrical engineer with the Dayton Electrical Manufacturing Company, of Dayton, Ohio, recently accepted a position in the motor engineering department of the General Electric Company at West Lynn, Mass.

MR. F. W. SCOTT, former transmission engineer for the Hydroelectric Power Commission of Ontario, has resigned and is making a specialty of the construction of complete transmission systems by contract. His address is 705 Builders' Exchange, Winnipeg, Man.

MR. J. C. RUNYON has been appointed superintendent of the Intervale Electric Company, of Yonkers, N. Y. For the last two years Mr. Runyon has successfully conducted an electrical contracting and engineering business in Rahway, N. J.

MR. C. C. CARR, formerly in the telephone engineering department of the Western Electric Company, New York, has been transferred to the company's headquarters in Antwerp, Belgium, where business is conducted under the title of The Bell Telephone Manufacturing Company.

MR. E. C. CREAGH has established a consulting electrical engineering practice in Dunedin, N. Z. Mr. Creagh was for two years with the British Westinghouse Electric and Manufacturing Company at Manchester, England. Prior to this he was with Messrs. Noyes Bros. in New Zealand.

MR. JOHN W. LIEB, JR., third vice-president of the New York Edison Company, was the guest of honor at a dinner given him at Delmonico's in New York City on Friday evening, February 11, by the council of the New York Edison Company, in honor of the fiftieth anniversary of his birth.

MR. G. F. CHELLIS, formerly with J. G. White and Company, New York, has for the past eight months been associated with the electrical department of the Sanitary District of Chicago, as construction superintendent, with headquarters at 31st Street and Western Avenue, Chicago, Ill.

MR. HENRY C. CLEMENT, who until recently had charge of the valuation of electrical equipment for power and substations in and about New York City, for the Public Service Commission, First District, has resigned to join the central station department of the General Electric Company, New York City.

MR. E. F. STONE, who for a number of years has been with the Norfolk and Portsmouth Traction Company, Norfolk, Va., as superintendent of distribution, has resigned to accept a position with the Pueblo and Suburban Traction and Light Company, Pueblo, Col., as superintendent of light and power distribution.

Mr. A. D. Miller has been appointed local manager of the Central California Traction Company, at Stockton, Cal. This company is operating an interurban third-rail road between Stockton and Lodi, and is building an extension to Sacramento. Mr. Miller held a similar position with the Reno Traction Company.

Mr. W. M. Shallcross has left the By-Products Coke Corporation to enter the engineering department of the Cutler-Hammer Manufacturing Company, of Milwaukee, Wis. Prior to going to Milwaukee Mr. Shallcross made a two-weeks' examination of the electrical property of the Philadelphia Rapid Transit Company.

Mr. Louis B. Magid, president of the Piedmont Power Company, Atlanta, Ga., has removed his own and the company's offices from 811 English-American Building, to 1014-1034 Candler Building, Atlanta. This company is developing a large hydroelectric project on the Tugaloo River, Georgia, and will build a 90-mile transmission line to Atlanta.

Mr. S. D. Levings formerly technical editor of the *Telephone Weekly* has become assistant to Mr. J. B. Adams, cable engineer for the Waterbury Company, 80 South Street, New York City. Mr. Levings will be engaged in work incident to the manufacture and installation of lead covered cables for telephone, electric lighting, power, and street railway work.

Obituary

Mr. Dirk Kos died in Amsterdam, Holland, on December 23, 1909, after a short illness. Mr. Kos was born in Ursem, Holland, on April 15, 1880. In 1898 he entered the Polytechnical Institute of Delft, graduating as a mechanical engineer in 1902, after which he took a post-graduate course in electrical engineering in the Polytechnical Institute of Karlsruhe. Subsequently he came to the United States, remaining for a number of years, during which period he held positions with various companies. Early in 1908 he returned to Europe to accept a position as electrical engineer with the Allgemeine Elektricitats Gesellschaft, of Berlin. Mr. Kos was admitted to membership in the Institute as an Associate on June 21, 1907.

Library Accessions*

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Mining Congress. Monthly Bulletin Vol. 13, Nos. 1–2. Denver, 1910. (Gift.)

American Philosophical Society. List of Members February 1910. Philadelphia, 1910. (Exchange.)

American Railway Association. Proceedings of Special meeting Jan. 27, 1910. New York, 1910. (Gift of American Railway Association).

Bekanntmachung uber Prufungen und Beglaubigungen durch die elektrischen Prufamter. Nos. 42–47 n.p. n.d. (Gift Physiklaisch-Technischen Reichsanstalt.)

Bibliographical sketch of L. A. Bauer. (Reprinted from National Cyclopedia of American Biography) New York, 1909. (Gift of Department of Terrestrial Magnetism, Washington, D. C.)

Carnegie Institution of Washington, Department of Terrestrial Magnetism. Annual Report of the Director 1909 n.p. n.d. (Gift of Department of Terrestrial Magnetism, Washington, D. C.)

Clarkson Bulletin, Vol. 7, No. 1, January 1910. Potsdam, 1910. (Gift.)

*The Library Accession List published every month in the Proceedings includes additions to the Library of the Institute only. Similar accession lists of the Libraries of the American Institute of Mining Engineers and the American Society of Mechanical Engineers are published by those societies. Copies of these lists may be obtained without charge upon application to the secretary of the Institute.

Distribution of the magnetic declination in Alaska and adjacent regions for 1910. By R. L. Faris. (Appendix No. 4—Report for 1909.) Washington, 1910. (Gift of U. S. Coast and Geodetic Survey.)

Elektrisch betriebene Entwasserungsanlage im Gebiete der Maas Mundung. (Allgemeine Elektricitats-Gesellschaft, Jan. 1910.) (Gift.)

Elektrischer Antrieb in Baumwollspinnereien. n.p. n.d. (Gift of Allgemeine Elektricitats-Gesellschaft.)

Elektrisches Pflugen. (Allgemeine Elektricitats-Gesellschaft. Jan. 1910.) (Gift.)

Experimental investigation of Dip needle corrections. By P. H. Dike. (Reprint Terrestrial Magnetism, Sept. 1909.) n.p. n.d. (Gift of Department of Terrestrial Magnetism, Washington, D. C.)

Influence of Forests on Climate and on Floods, a report. (House of Representatives, U. S. Committee on Agriculture). Washington, 1910. (Gift.)

Inverted Rotary converter case. Lamme patent no. 606,015 Westinghouse Electric & Manufacturing Company *vs.* Allis-Chalmers Co. and Bullock Electric Manufacturing Co. Opinion Court of Appeals. Jan. 20, 1910. New York, n. d. (Gift of W. J. Jenks.)

Launching of the "Carnegie" June 12, 1909. By Mrs. L. A. Bauer. (Reprint Terrestrial Magnetism, Sept. 1909.) n.p. n.d. (Gift of Department of Terrestrial Magnetism, Washington, D. C.)

Lewis Institute. Director's Report 1909. Chicago, 1910. (Gift.)

Music and science. (Philosophical Society of Washington Bulletin, Vol. 15, p. 169-187.) Washington, 1910. (Gift of Society.)

New York Public Service Commission, First District Summary of quarterly reports of street railway companies operating in the City of New York, for July–Sept., 1909. New York, 1909. (Exchange.)

Simon Newcomb Memorial Addresses.

New York State Public Service Commission. 2d District Annual Report 2d, 1908. Vols. 1–3; 3d, Albany, 1909, 1910. (Exchange.)

——Matter of complaint of the City of Auburn *vs* Auburn and Syracuse Electric Railroad Company and Auburn and Northern Electric Railroad Company in Reference to their track conditions and proposed switches in State Street, in said city. Opinion of Commission Jan. 31, 1910. n.p., 1910. (Exchange.)

——Matter of the complaint of James Morris against Buffalo, Lockport and Rochester Railway Company. Opinion of the Commission. Jan. 26, 1910. n.p., 1910. (Exchange.)

——Passenger train delay bulletin Nos. 20, 21, n.p. 1909. (Exchange.)

Non-magnetic gas engine of the "Carnegie" By James Craig, Jr. (Reprint Terrestrial Magnetism, Sept. 1909.) n.p. n.d. (Gift of Department of Terrestrial Magnetism, Washington, D. C.)

Polytechnic Institute of Brooklyn. Catalogue of the College of Engineering 1910–11. Brooklyn, n.d. (Gift.)

Results of magnetic observations made by the coast and geodetic survery between July 1, 1908 and June 30, 1909. By R. L. Faris. (Appendix No. 3—Report 1909.) Washington, 1910. (Gift of U. S. Coast and Geodetic Survey.)

(Philosophical Society of Washington, Bulletin Vol. 15, p. 133–167.) Washington, 1910. (Gift of Society)

South African Institute of Electrical Engineers. Transactions, Vol. 1-date. Johannesburg, 1909-date. (New Exchange.)

Study of base and bearing plates for columns and beams (Bulletin No. 35, University of Illinois, Engineering Experiment Station.) By N. C. Ricker. Urbana, 1909. (Gift.)

U. S. Library of Congress. Report of Librarian 1909. Washington, 1909. (Gift.)

——Publications issued since 1897. Washington, 1910. (Gift.)

University of Minnesota. Bulletin of the College of Engineering and the Mechanic Arts. 1909-10 (no. 7.) Minneapolis, 1909. (Gift of University of Minnesota.)

Washington University Record. Vol. 5, No. 3. March 1910. St. Louis, 1910. (Gift of Washington University.)

Wireless telephones and how they work. By James Erskine-Murray. London 1910. (Gift of McGraw-Hill Book Co.)

Trade Catalogues.

American Radiator Co., Chicago, Ill. "The Ideal Fitter," a catalogue of supplies for boilers, radiators, and general heating. 282 pp.

——Ideal sectional boilers for steam and water. 32 pp.

——Ideal 48-inch sectional boilers. 32 pp.

——Ideal round boilers for steam and water. 32 pp.

——Vento cast-iron, hot-blast heater for heating, ventilating, drying, and brine cooling. 48 pp.

Asbestos Protected Metal Co., Canton, Mass. Asbestos protected metal for roofing, siding, ceiling, and interior finish. 8 pp.

Cutler-Hammer Clutch Co., Milwaukee, Wis. Cross section of a Cutler-Hammer lifting magnet. 12 pp.

——Elevator Controllers; a booklet describing the Cutler-Hammer controlling devices for elevators. 128 pp.

General Electric Co., Schenectady, N. Y. Bulletin No. 4703A, Variable release air brake equipment. 11 pp.

——Bull. No. 4714, Railway signal volt-ammeter, type S. 3 pp.

——Bull. No. 4715, G. E. 210 railway motor. 16 pp.

——Price list No. 5211 of G. E. Tantalum incandescent lamps. 5 pp.

——Building Lighting with General Electric Tungsten and Tantalum lamps. 16 pp.

——November 1909 Index to bulletins published. 9 pp.

Kansas Gas, Water, Electric Light and Street Railway Association, Wichita, Kansas. Official convention manual of 12th annual meeting, held September 23 and 24, 1909. 36 pp.

Pettingell-Andrews Co., Boston, Mass. Juice, Feb. 1910—a booklet giving information about Pettingell electrical goods. 17 pp.

Terry Core Drill Co., New York, N. Y. Core drills for prospecting, blasting, testing, etc. 60 pp.

Wagner Electric Mfg. Co., St. Louis, Mo. Bull. 89, Type BW polyphase induction motor. 8 pp.

Western Electric Co., Hawthorne, N. Y. Bull. No. 5111, Direct driven generators, type "LL." 12 pp.

——Bull. No. 5230, Polyphase induction motors. 12 pp.

——Bull. No. 5352, Hawthorne fan motors. 28 pp.

UNITED ENGINEERING SOCIETY
GIFT OF E. E. OLCOTT

Albany Institute. Transactions. Vol. 5. Albany, 1867.

New York State. Adjutant General. Annual report. Vol. 3. Albany, 1868.

New York, State Engineer and Surveyor. Annual report on canals 1862, 1864. Albany, 1863, 1865.

——Annual report on railroads. 1862, 1865. Albany, 1863, 1866.

New York (State) Railroad Commissioners. Report Vol. 1, 1885. Albany, 1886.

Sweet, S. H. Documentary sketch of New York State canals. Albany, 1863.

Register till patent meddelade af Kungl. Patentbyran. 1885-1908 and supplement to 1905. Stockholm, 1890–1909. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1909-1910.

PRESIDENT.

(Term expires July 31, 1910.)

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(Term expires July 31, 1910.)
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(Revised to January 1, 1910)

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NOTE

The following paper is to be read at the 245th meeting of the American Institute of Electrical Engineers in **New York, April 15, 1910.** This paper is to be presented under the auspices of the Educational Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

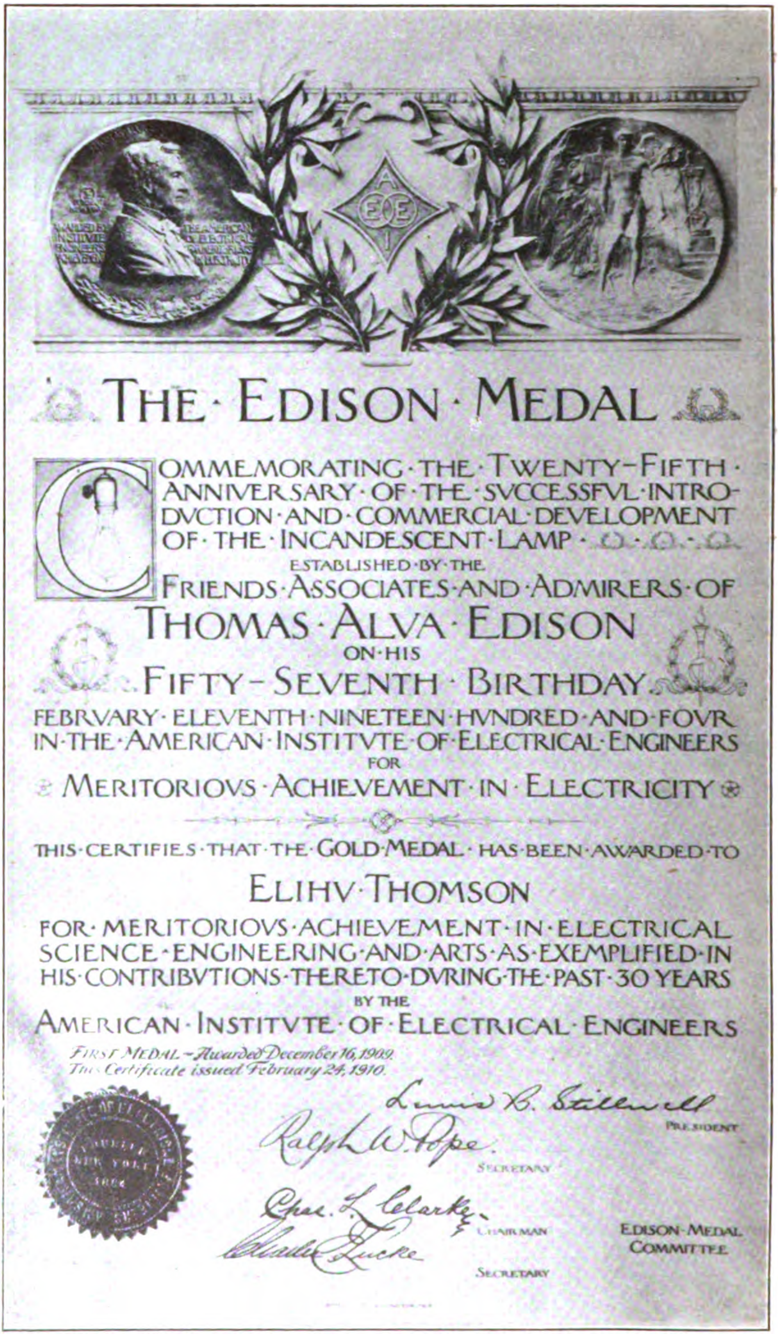
Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Prof. Dugald C. Jackson, Chairman Educational Committee, Massachusetts Institute of Technology, Boston, Mass,** so that they will be received not later than April 12, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

IMPORTANT

Since this paper was printed the meeting has been postponed from April 8 to April 15, and the date of release is changed to April 16.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PROCEEDINGS

OF THE

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OF

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Vol. XXIX **May, 1910** No. 5

Institute Meeting at San Francisco, Cal., May 5-7, 1910

The success of the Southern Convention at Charlotte, N. C., leads us to hope for an equally enthusiastic and successful meeting at San Francisco on May 5, 6 and 7, 1910. As announced in previous issues of the PROCEEDINGS, the meeting will be under the auspices of the High-Tension Transmission Committee, Ralph D. Mershon, Chairman. The members on the Pacific coast have been very active in their preparations for this meeting, and through their efforts, some of the features arranged for will be of unusual interest. In San Francisco visitors will be given an opportunity for sight-seeing trips around the city, which will include visits to the local generating stations, and the Entertainment Committee has arranged for special parties to visit points of unprofessional interest. On the evening of May 6 the San Francisco Section will give a reception to President Lewis B. Stillwell and the visiting members. The Pacific Gas and Electric Company has very kindly arranged for a tour of inspection of several of its mountain plants, and will provide special transportation and entertainment for those making the trip. The party will leave San Francisco on the evening of May 8, and in the course of the tour will make a side trip to the Big Bend plant of the Great Western Power Company, as guests of the latter company. The entire trip will require four days. Arrangements have also been made for members who visit Seattle, Portland and Los Angeles, to be accorded the privilege of inspecting electrical plants in these cities.

The technical papers to be presented are as follows:

Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants Under Pacific Coast Conditions. By A. M. Hunt, Electrical Engineer, San Francisco, Cal.

Hydroelectric Power as Applied to Irrigation. By John Coffee Hays, Consulting Engineer, and President, Mt. Whitney Power Company, Visalia, Cal.

The Developed High Tension Net-Work of a General Power System. By Paul M. Downing, Engineer, Operation and Maintenance, Pacific Gas and Electric Company, San Francisco, Cal.

Parallel Operation of Three-Phase Generators with Their Neutrals Interconnected. By George I. Rhodes, Assistant Engineer, Interborough Rapid Transit Company, New York City.

Observations of Harmonics in Current and in Voltage Wave Shapes of Transformers. By John J. Frank, Assistant Engineer, Transformer Department, General Electric Company, Pittsfield, Mass.

Transmission Line Crossings of Railroad Rights-of-Way. By Allen H. Babcock, Electrical Engineer, Harriman Lines, San Francisco, Cal.

The papers by Messrs. Hunt, Hays and Downing were published in the Institute PROCEEDINGS for April. The papers by Messrs. Rhodes and Frank will appear in the May PROCEEDINGS. The paper by Mr. Babcock will not be printed in advance.

The professional sessions will be held in the auditorium of the Home Telephone Company Building, 333 Grant Avenue, San Francisco, Cal.

The Institute will be officially represented by President Lewis B. Stillwell, and Secretary Ralph W. Pope, of New York.

Leading hotels in San Francisco in the vicinity of the meeting place are: Hotel Manx, $1.50 up; Hotel St. Francis, $2.00 up; Palace Hotel, $2.50 up. These rates are on the basis of the European plan.

Hotels at other cities on the Pacific coast which may be visited by members are: Seattle, Hotel Butler and Hotel Washington; Portland, Ore., Hotel Portland; Los Angeles, Hotels Haywards, Alexandria, and Vannuys.

Non-members, as well as members, are cordially invited to attend this meeting.

Annual Meeting of A.I.E.E. at at New York, May 17, 1910

The annual meeting of the Institute will be held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Tuesday, May 17, 1910. The Board of Directors will present its report for the fiscal year ending April 30, 1910. This will include a detailed statement of the financial status of the Institute, and will show the work of all the standing and special committees for the year. At this meeting the result of the membership vote for the offices to be filled for the ensuing administration year will be announced. The officers to be elected are: the president; three vice-presidents; four managers; the treasurer, and the secretary. In addition to the business transacted a paper will be presented by Mr. John W. Howell, Engineer, Lamp Works, General Electric Company Harrison, N. J.

Special Meeting of A.I.E.E. at New York, May 27, 1910

A special meeting under the auspices of the Railway Committee will be held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Friday evening, May 27, 1910. The following papers will be presented: *The Application of Porcelain to Strain Insulators*, by W. H. Kempton; *Electric Railway Overhead Construction*, by W. N. Smith. The papers were received at Institute headquarters too late to be printed in the May PROCEEDINGS, but they will appear in a subsequent issue. Advance copies of the papers will be available a few days before the meeting and will be furnished on application to the Secretary.

Annual Convention of A.I.E.E. for 1910, Jefferson, N. H., June 27-30, 1910

Upon the recommendation of the committee appointed by President Stillwell early in February to consider and report on a suitable date and place for the Annual Convention of the A.I.E.E. for 1910, it was decided by the Board of Directors at its meeting on April 15, 1910, that the convention will be held at The Waumbeck and Cottages, Jefferson, N. H., in the White Mountain district, on Monday, Tuesday, Wednesday and Thursday, June 27, 28, 29 and 30, 1910. The White Mountains are too well known to warrant any description here. The Waumbeck is delightfully situated, at an altitude of 1,500 feet, and affords a magnificent view of the mountains. The hotel and cottages are equipped with every convenience and comfort and pleasure seekers will find ample

opportunity for diversion in golfing, fishing, trap-shooting, and rambling, riding and driving in the mountains. Jefferson is distant from New York about 10 hours on the train, from Boston seven hours, and from Philadelphia, 12 hours.

The technical program is being arranged by the Meetings and Papers Committee, and the titles of the papers to be presented will be announced in the June PROCEEDINGS.

Institute Meeting at New York, April 15, 1910

The two hundred and forty-seventh meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West 39th Street, New York City, on Friday evening, April 15, 1910. The meeting was under the auspices of the Educational Committee, and was called to order by President Lewis B. Stillwell at 8:25 p.m. The Secretary announced that at the meeting of the Institute Board of Directors held during the afternoon 131 Associates were elected, and four Associates were transferred to the grade of Member. The names of Associates elected, and those transferred, are printed elsewhere in this issue. The Secretary further announced that the report of the Convention Committee, recommending the time and place of the next Annual Convention, had been favorably acted upon by the Board of Directors, and that the convention this year will be held at The Waumbeck and Cottages, Jefferson, N. H., on June 27-30, 1910. President Stillwell then introduced Dr. Samuel Sheldon, who presented in abstract a paper entitled "Education for Leadership in Electrical Engineering." The paper was discussed by, Dr. Charles S. Howe, president of the Case School of Applied Science, Cleveland, O., Dr. Abraham, Flexner, of the Carnegie Foundation, Mr. John W. Lieb, Jr., Professor D. C. Jackson, Dr. A. E. Kennelly, and Mr. William McClellan.

Joint Meeting at New York, April 12, 1910

A meeting of the American Society of Mechanical Engineers was held in the Engineers' Building on April 12, 1910, with the coöperation of the American Institute of Electrical Engineers. The subject of the meeting was "Electric Drive in Machine Shops."

The following papers were contributed by the A.S.M.E., and presented by their respective authors:

Economy of the Electric Drive, by A. L. DeLeeuw.

Economical Features of Electric Motor Applications, by Charles Robbins.

Mechanical Features of Electric Driving, by John Riddell

In behalf of the A.I.E.E., Mr. Charles Fair presented a paper entitled

Motor Application to Machine Tools.

The papers were discussed by Messrs. Henry Hess, L. R. Pomeroy, Gan Dunn, and Fred L. Eberhardt.

The proceedings at this meeting will be published in a future issue of *The Journal of the American Society of Mechanical Engineers.*

The Southern Convention

The meeting of the Institute at Charlotte which opened on March 31 exceeded the anticipations of the Institute officers, especially in the attendance from distant points. The usual date of the Annual Convention during the last week in June has discouraged any recent attempt to hold it in the South. President Stillwell satisfied himself that a special meeting in that territory during the Easter holidays would strengthen the Institute, and lead to the development of greater interest in its affairs. A sufficient number of members could not be concentrated from the North to warrant the running of a special train over the Southern Railway, so that proposed feature of the program was necessarily abandoned. The Secretary left Washington on March 29, where he was joined by a delegation of 15 from Pittsburg, arriving at Charlotte, N. C., in the

evening where they were met by the Local Committee and escorted to the Hotel Selwyn.

On account of the late arrival of the train from the North on March 30, the morning session was cancelled. Many of the members who had already arrived were given an opportunity to visit two neighboring cotton mills and a producer gas plant. The influx of members from various parts of the South led to a change in the title of the gathering, from a "Special Meeting" to "The Southern Convention" The total registration was 549 which included 411 Charlotte citizens.

Wednesday's session was called to order by President Stillwell at 2 p.m. nearly 200 being present, and the attendance continued at about that number throughout the Convention. Chairman Lee of the Local Committee, in introducing Mayor Hawkins, said that they had long desired that a meeting of the Institute should be held "down South," and were highly gratified at the attendance and enthusiasm shown. All were very proud of Charlotte as a thriving and fast growing city. Mayor Hawkins, in behalf of the city of Charlotte in a spirited address welcomed the visiting engineers. He told the visitors something of the industrial evolution that has taken place in the South in recent years and gave large credit to the great work achieved by the electrical engineering profession. He also spoke of Charlotte and the part that the Southern Power Company has played in her industrial uplift.

President Stillwell in responding, expressed the pleasure of the members in again meeting in North Carolina. "We are always willing to meet whereever papers of Institute grade are produced," said he. "While many of the members, he continued, are localized in a few of the large cities, notably New York, Philadelphia, Chicago, Boston, San Francisco, Schenectady and Pittsburg, the Institute is a national and by no means a local organization." This fact, Mr. Stillwell declared, was emphasized by the three papers appearing in the April number of the PROCEEDINGS from three engineers connected with the Southern Power Company alongside three papers from engineers in San Francisco. Reference was made to the work that is being achieved in the South by the electrical engineers. Some appreciation of this fact can be had when it is stated that the 100,000 horse power necessary to drive the textile plants represent the work in foot pounds of 5,000,000 men.

In closing, President Stillwell created much enthusiasm by his direct allusion to Mayor Hawkins' address in the following words: "I have visited in North Carolina and Charlotte before. I have heard many addresses of welcome and otherwise. But never have I listened to a speech in Charlotte that did not have to do with the Mecklenburg Declaration of Independence. Mayor Hawkins is the first man to omit any reference to this event in history and as a Pennsylvanian, I desire to express to him my appreciation of the delicacy of the compliment."

The Secretary read letters from various organizations in Charlotte extending courtesies to the visitors. The regular program of the convention was then taken up, the first paper being that of Mr. Milmow printed in the April PROCEEDINGS. The evening session was occupied by Mr. E. E. F. Creighton, who gave a talk on protection from lightning accompanied by very interesting demonstrations. The session of Thursday morning, March 31, was occupied with the presentation and discussion of the papers by Mr. Carl Hering and Dr. Arthur E. Kennelly, printed in the March PROCEEDINGS, and the paper by W. S. Lee, Jr., which appeared in the April number. An afternoon reception in honor of the visiting ladies was given by Mrs. Stuart W. Cramer at her home on Thursday, and in the evening a reception and dance was enjoyed by all at the auditorium. The closing technical session of the convention was held at

2.30 p.m., March 31, when the paper by L. C. Nicholson printed in the March PROCEEDINGS was read and discussed.

The Committee on Resolutions presented the following report just prior to adjournment, which was adopted by a rising vote.

At the afternoon session of the Southern Convention of the American Institute of Electrical Engineers, March 31, 1910, it was unanimously voted that the following resolutions be adopted and spread on the records of tne Institute:

I

Resolved, that the Institute recognizes with keen satisfaction the substantial development of the Institute in scope and influence throughout the various sections of the country, notably as evidenced by the initiative and enterprise of the Southern members in so successfully organizing and carrying out the first local Convention of the Institute.

II

Resolved, that the Institute notes with gratification the important part which electrical power plays in the industrial development of the South and marks with deep satisfaction the evidence of appreciation of this public service by the community and the State.

III

Resolved, that the Secretary of the Institute be requested to express the hearty thanks of the Convention for the many courtesies extended and for the evidences of traditional southern hospitality by the citizens and organizations of the City of Charlotte, and that the Secretary transmit these resolutions to His Honor, Mayor Hawkins, Mrs. Stuart W. Cramer, the Southern Manufacturers Club, the Colonial Club, The Greater Charlotte Club, the Southern Bell Telephone and Telegraph Company, The American Telephone and Telegraph Company, the Western Union Telegraph Company, the Charlotte Consolidated Construction Company, the Highland Park Manufacturing Company, the Chadwick-Hoskins Company and the Southern Power Company.

IV

Resolved, that the Institute congratulates the Local Committee and its Chairman on the highly successful results of their efforts, and the standard set for future conventions of this character.

CHARLES F SCOTT, Pittsburg, Pa.
W. I. SLICHTER, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.
Committee on Resolutions

Charlotte, N. C.
March 31, 1910

Among those who participated in the discussion of the papers were C. F. Scott, W. S. Lee, A. W. Henshaw, D. B. Rushmore, Carl Hering, P. H. Thomas, A. M. Schoen, H. N. Mullen, W. L. Waters, E. W. Shedd, L. W. Jenks, J. A. Sanford, Jr., and D. J. Kerr.

On Friday April 1 the visitors accompanied by a goodly number of Charlotte people were the guests of the Southern Power Company, and were provided with a special train over the Seaboard Air Line to Great Falls, S. C., where an opportunity was given to inspect the two hydroelectric power plants at that point, and at Rocky Creek, about two miles beyond, at a beautiful spot halfway between, a typical Southern barbecue was served at noon which was a culinary novelty to most of the members, and was thoroughly enjoyed. Upon the return of the train to Charlotte the larger proportion of the members started homeward at once, while a few remained over until the following day. All were highly gratified with the entire proceedings of the convention, and especially the kindly manner in which everything was done to make the convention an event to be remembered with pleasure by all who were so fortunate as to attend.

Directors' Meeting, April 15, 1910

The regular monthly meeting of the Institute Board of Directors was held at 33 West 39th Street, New York City, on Friday, April 15, 1910. The directors present were: President Lewis B. Stillwell, New York; Past-president Henry G. Stott, New York; Vice-presidents Paul Spencer, Philadelphia, Pa., Calvert Townley, New Haven, Conn.; Managers H. W. Buck, New York, Percy H. Thomas, New York, D. B. Rushmore, Schenectady, N. Y., W. G. Carlton, New York, Charles W. Stone, Schenectady, N. Y., A. W. Berresford, Milwaukee, Wis., W. S. Murray, New Haven, Conn., H. H. Norris, Ithaca, N. Y., Severn D. Sprong, New York; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary Ralph W. Pope, New York.

One hundred and thirty-one candi-

dates for admission to membership in the Institute as Associates were elected.

Forty-two Students were declared enrolled.

Four Associates were transferred to the grade of Member, as follows:

CLIFFORD SHERRON MACCALLA, Assistant to General Manager, Washington Water Power Company, Spokane, Wash.

JOHN F. VAUGHAN, Engineer, Stone and Webster Engineering Corporation, Boston, Mass.

WILBUR HAYES THOMPSON, Sup't. and Chief Engineer, American Telegraphone Company, Wheeling, W. Va.

FRANK BALDWIN JEWETT, Transmission and Protection Engineer, American Tel. and Tel. Company, New York City.

Associates Elected April 15, 1910

ABER, GUY LE ROY, Electrical Contractor, Guy L. Aber & Co., Liberty St.; res., 22½ W. Morris St., Bath, New York.

BARRINGER, ORMOND LONG, Automobile Engineer, Ormond L. Barringer Co., 7 West 8th St., Charlotte, N. C.

BENNER, EDWARD HOPKINS, Engineer, D. C. and W. B. Jackson, Boston; res., 122 Grove St., Wellesley, Mass.

BIRCH, ARTHUR LEONARD, Engineer, Crocker Wheeler Co., Ampere, N. J.; res., 137 West 145th St., New York City.

BLACKBURN, LEONARD ANDERSON, Draftsman, Southern Power Co.; res., 401 East Boulevard, Charlotte, N. C.

BOOR, EVERETT B., General Electric Co.; res., 7 State St., Schenectady, N. Y.

BOWMAN, DONALD, Designer, Commonwealth Edison Co., 84 Market St.; res., 1220 E. 61st St., Chicago, Illinois.

BULLIS, SETH MADISON, Electrical Engineer, Vicksburg Light & Power Co., Vicksburg, Mississippi.

BURKE, DAVID WARDEN, District Engineer, Westinghouse Electric & Mfg. Co., 103 Lewisohn Building, Butte, Montana.

BURNES, PETER A., Manager, Office Dept., 50 Market Street; res., 138 No. Clinton St., Poughkeepsie, N. Y.

BUSSEY, HENSON ESTES, District Engineer, General Electric Co., Empire Building, Atlanta, Ga.

CARLSON, ERIC E., Illinois Steel Co., 768 Delaware Street, Gary, Indiana.

CLARK, JAMES, JR., President, James Clark Jr. Electric Co., 520 W. Main Street, Louisville, Kentucky.

COOPER, WILLIAM RUSSELL, Electrician, Indianapolis Light & Heat Co.; res., 2331 Talbott Ave., Indianapolis, Ind.

CORWIN, MERTON J., Sales Engineer, Dean Electric Co., 1061 East Mercer St., Seattle, Wash.

DENIS, LEO G., Electrical Engineer, Commission of Conservation, Ottawa, Canada.

DOWNER, JOHN MORRILL, General Electric Co.; res., 29 Elder Street, Schenectady, N. Y.

DRESSER, RAYMOND EDGAR, Electrician, Boston Consolidated Mining Co., Garfield; res., 331 So. 8th East St., Salt Lake City, Utah.

EASTMAN, MORGAN LEONARD, Electrical Operator, Commonwealth Edison Co., res., 6506 Kimbark Ave., Chicago, Ill.

EIRICH, CARL, District Engineer, Pacific Telephone & Telegraph Co., 1320 S. Hope St., Los Angeles, Cal.

ELDEN, HARRY F., Electrical Engineering Department, The Edison Electric Illuminating Co., 39 Boylston St., Boston, Mass.

ELDER, L. R., Motor Specialist, General Electric Co.; res., 735 Hoyt St., Portland, Ore.

EMERY, HUGH HILDRETH, Superintendent, South Side Pumping Plant, United States Sugar and Land Co., Garden City, Kansas.

FAIR, CHARLES, Engineer, Power and Mining Engineering Department, General Electric Co., Schenectady, N. Y.

FILKINS, EARL LE ROY, Electro-Mechanical Engineer, The Milwaukee Electric Railway & Light Co., Milwaukee, Wis.

FOX, JOHN W., Commercial Engineer, Westinghouse Electric & Mfg. Co., Trust Bldg.; res., 907 W. 4th St., Charlotte, N. C.

FRAZIER, CHAUNCEY E., Superintendent of Power, Hazel Atlas Glass Co., Wheeling, West Virginia.

FRENCH, BURTON, Electrical Engineer, Consumers Electric Co., 139 So. Rampart St.; res., 3018 Prytania St., New Orleans, La.

FRIES, HENRY ELIAS, President, The Fries Mfg. & Power Co.; res., 208 S. Main St., Winston-Salem, N. C.

GARDINER, JOHN HOWLAND, District Sales Manager, Nernst Lamp Co., 607 Boylston St., Boston, Mass.

GARLAND, NATHAN M., District Sales Manager, Ohio Brass Co., 30 Church St., New York City.

GAUTHIER, GEORGE J., Engineer and Draftsman, Oklahoma Railway Co., Oklahoma City, Oklahoma.

GEARY, THOMAS JAY, JR., Electrician, Miller and Lux, Inc., Butchertown; res., 422 Valencia St., San Francisco, Cal.

GILL, JOSEPH RALPH, Electrician in charge of Power Plants, Navy Yard, Boston, Mass.

GLODELL, LEROY MARCUS, Chief Engineer, National Folding Box & Paper Co.; res., 463 Ferry St., New Haven, Conn.

GRAY, JESSE EDWARD, General Power Engineer, Narragansett Electric Lighting Co.; res., 45 Waterman St., Providence, R. I.

GREESON, EVERETT MATTHEW, Corresponding Engineer, Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.

GROSSMAN, HENRY M., Testing Engineer, Lincoln Electric Co.; res., 1784 East 26th St., Cleveland, Ohio.

HACKEL, JACOB MOVESTOWITCH, Superintendent, Russian Westinghouse Electric Co., St. Petersburg, Russia.

HALE, JOSEPH WOODWELL LEDWIDGE, Instructor in Electrical Engineering, Pennsylvania State College, State College, Pa.

HANCOCK, JOHN W., General Manager, Roanoke Railway and Electric Co., Roanoke, Virginia.

HARDING, REYNOLD MUNROE, Superintendent, Light and Power, Pensacola Electric Co., Pensacola, Florida.

HARTE, CHARLES RUFUS, Assistant Engineer, New York, New Haven & Hartford Railroad, Room 308 Railroad Bldg., New Haven, Conn.

HARZA, LE ROY FRANCIS, Hydraulic Engineer, D. W. Mead; res., 124 W. Dayton St., Madison, Wis.

HEALD, HAROLD WESTON, Inspector, Providence Telephone Company, 19 Beacon Avenue, Providence, R. I.

HEIM, HARRY RUSSELL, Salesman, Westinghouse Electric & Mfg. Co., 936 Metropolitan Life Insurance Bldg., Minneapolis, Minn.

HERBERT, CLAUDE DRAKE, Salesman, Westinghouse Electric & Mfg. Co., 165 2nd Street, San Francisco, Cal.

HEYER, GEORGE KELLOGG, Electrical Engineer, Western Electric Co., 463 West St., New York City.

HILL, BRUCE VICKROY, General Foreman Electrolytic Division, Chicago Telephone Co., Chicago, Ill.

HIRAIWA, TAMEKICHI, Foreman, Construction Department, General Electric Co., Schenectady, N. Y.

HODGSON, OLIVER, Inspector, N. Y. C. & H. R. Railroad, 335 Madison Ave.; res. 153 E. 179th St., New York City.

HOOPER, BURT EVERETT, Superintendent, American River Electric Co., Placerville, Cal.

HORNE, GEORGE HENRY, Electrical Engineer, Pittsburg Transformer Co.; res., 846 N. St. Clair Street, Pittsburg, Pa.

HULETT, FRED MANKER, Inspector of Equipment, South West Missouri Railroad Co.; res., 206 W. 3rd Street, Webb City, Mo.

IRELAND, LYAL GIBSON, Construction Engineer, Smith, Kerry and Chace, 551 Confederation Life Bldg., Toronto, Ont.

JONES, JOHN MCLAURIN, Assistant, Mill Power Dept., Southern Power Co., Trust Building, Charlotte, N. C.

JONES, REID, Student, Cornell University; res., 58 Thurston Avenue, Ithaca, N. Y.

KARTAK, FRANZ AUGUST, Assistant in Electrical Engineering, University of Wisconsin, Madison, Wis.

KILEY, WILLIAM RICHARD, Electrical Engineer, West Virginia Pulp and Paper Co., Covington, Virginia.

KLEFFEL, HARRISON E., Draftsman, The Southern Power Co., Trust Building, Charlotte, N. C.

KLENK, FERNAND FEIR, Student, Pratt Institute, Brooklyn; res., 136 West 13th St., New York City.

LATTIN, ROBERT BIDWELL, Electrical Engineer, The Johns-Pratt Co.; res., 17 Warrenton Ave., Hartford, Conn.

LEFFERTS, EDWIN BOUGHTON, Estimator on Electrical Machinery, General Electric Co.; res., 1 Division St., Schenectady, N. Y.

LEWIS, FRANK PERCY, Master Electrician, Navy Yard; res., 215 Lafayette Ave., Brooklyn, N. Y.

LIPSCOMB, GASTON JOEL, W. R. Grace & Co., Iquique, Chile.

MAINWARING, WILLIAM HAMER, Salesman, Westinghouse Electric & Mfg. Co.; res., 33 Park Avenue, Wilkes-Barre, Pa.

MAMBERT, STEPHEN BABCOCK, Mac-Arthur Brothers & Winston and Co., Contractors Bldg., Brown Station, N. Y.

MARRON, JOHN T., President and Manager, Electric Construction & Machinery Co., 1622 2nd Ave., Rock Island, Ill.

MASSEY, BENJAMIN HARPER, Constructing Engineer, Southern Power Company, Charlotte, N. C.

MATTHEWS, HOWARD DAVID, Electrical Engineer, General Electric Co.; res., 362 McClellan St., Schenectady, N. Y.

MCIVER, ALEXANDER, Heavy Traction Department, Westinghouse Electric & Mfg. Co., 165 Broadway, New York City.

MCLELLAN, ROSS LE ROY, Fairbanks Morse Electric Mfg. Co., res., 223 West 21st St., Indianapolis, Ind.

MCMANUS, JOHN ALOYSIUS, Patent Department, General Electric Co. res., 39 Perley Street, West Lynn, Mass.

MERWIN, LOUIS TUNIS, Electrical Engineer, Goldfield Consolidated Mines Co., Goldfield, Nevada.

MILLAR, STANLEY JAMES, Engineering Draftsman, Locomotive Dept., Queensland Railways, Ipswich, Queensland, Australia.

MOHR, STANLEY MELBOURNE, Superintending Engineer of Sub-stations, The Russian Westinghouse Co., St. Petersburg, Russia.

MOLINARD, WILLIAM ROBINSON, General Manager, Cobalt Hydraulic Power Co., Ltd., Cobalt, Ontario.

MOMOTA, SADAJI, Designing Engineer, Shibaura Engineering Works, Shibaku, Tokio, Japan.

MONTGOMERY, JOHN, Chief of Meter Service Dept., Mexican Light & Power Co., Mexico City, Mex.

MOULTON, WALTER ROSS, National X-ray Reflector Co., 245 Jackson Blvd., Chicago, Ill.

MURPHY, JOHN JOSEPH, Superintendent of Construction, Electric Construction & Machinery Co., Rock Island, Ill.

NARAYAN, SHIO, Operator, Power Station, Jhelum Power Installation, Mohora, Kashmir, India.

NICK, EDWIN WILLIAM, Electrical Foreman, Dept. of Const. & Engg., Atlantic Div., Isthmian Canal Commission Gatun, C. Z.

NOERAGER, ARNOLD JEREMIAH, Electrician, Braden Copper Company, Rancangua, Chile.

OLIVER, FRANKLIN P., District Plant Chief, American Tel. & Tel. Co., Room 403, 78 South Pryor St., Atlanta, Ga.

PATTON, WILLIAM RIGHT, Pacific Telephone and Telegraph Company, San Francisco, California.

PHIPPS, WILLIAM R., Superintendent, Brush Electric Light & Power Co., Galveston, Texas.

PIERCE, HOMER JAY, Division Equipment Engineer, Northwestern Telephone Exchange Co., Minneapolis, Minn.

PLUMER, EDWARD ASHBY, Commercial Engineering Department, American Telephone & Telegraph Co., 15 Dey St., New York City.

POATS, THOMAS GRAYSON, Associate Professor of Physics, Clemson College, Clemson College, S. C.

PYLE, JOHN CLIFFORD, Installation Agent, Los Angeles Gas and Electric Corporation, Los Angeles, Cal.

REAL, PAUL MIMRAD, Assistant Engineer, New York, New Haven & Hartford Railroad; res., 244 Whalley Ave., New Haven, Conn.

RITTENHOUSE, LEON HAWLEY, Associate Professor of Mechanics and Electricity, Haverford College, Haverford, Pa.

ROGERS, FRED ALEXANDER, Solicitor, Edison Electric Illuminating Co., 42 Main Street, Brockton, Mass.

RYDER, JOHN LYNN, Telephone Engineer, The Pacific Telephone and Telegraph Co., Los Angeles, California.

SAUNDERS, HUGH DARWIN, District Engineer, New York Telephone Co.; res., 669 Summer Avenue, Newark, N. J.

SCHERLING, GUSTAVE JOHN, Secretary and Treasurer, Dongan Electric Manufacturing Co., 52 Green Street, Albany, N. Y.

SCHNYDER, CESAR CHRISTOPHER WALTER Switchman, Automatic Electric Co., Chicago, Ill.

SCOTT, CARL FORSE, Commercial Engineer, Sprague Electric Company, 527 West 34th St., New York City.

SCOTT, WILLIAM GORDON, Construction Department, Allis-Chalmers-Bullock Co., Montreal, Quebec.

SEAVER, CHARLES HOMER, Associate Editor, Electrical Review and Western Electrician, 507 Marquette Bldg., Chicago, Ill.

SEEBER, REX ROBERT, Superintendent, Winona Copper Company, Winona, Mich.

SHAIN, DEWITT CLINTON, General Superintendent, American Gas & Electric Co., 30 Church St., New York City.

SIGG, JOHN JACOB, Manager, The Fries Manufacturing & Power Co., Winston-Salem, N. C.

SLIMP, JAMES ELBERT, District Sales Agent, The Ohio Brass Co., No. 30 Church Street, New York City.

SMALLHOUSE, A. B., Consulting Electrical & Mechanical Engineer, Electric Manufacturing and Repair Co., Salt Lake City, Utah.

STEPHENS, PHINEHAS VARNUM, Consulting Engineer, with Mr. Wm. F. Donnelly, 135 Broadway, New York City.

•STRONG, WILSON BUDD, 1st Lieutenant, Office of Auditor for Post Office Dept. Washington, D. C.

SULZER, WALTER, Draughtsman, Westinghouse Electric & Mfg. Co., Pittsburg; res., Braddock, Pa.

SUTTON, HENRY CRAIG, Meter Expert, Northwestern Corporation, Fenton Building, Portland.

SWALES, G. OSBORNE, Student, Washington State College; res., 507 Monroe Street, Pullman, Wash.

TARKINGTON, CLARENCE GAYE, Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa.

TERRELL, CHARLES FOSTER, System Operator, Seattle Electric Co.; res., 2804 12th Ave. N., Seattle, Washington.

THOMAS, GEORGE NEVIL, Engineer in Engineering Department, Canadian General Electric Co., Toronto, Ont.

THORNTON, FRANK, JR., Engineer, Heating Division, Westinghouse Electric & Mfg. Co., Pittsburg; res., 504 Jeannette St., Wilkinsburg, Pa.

TIMBIE, WILLIAM HENRY, Instructor of Industrial Electricity, Pratt Institute, Ryerson, St., Brooklyn, N. Y.

TOWNSLEY, ARTHUR WALLACE, Transformer Engineering Department, General Electric Co., West Lynn, Mass.

TRIPLETT, RAY LEON, Manager, Triplett Meter Co., Bluffton, Ohio.

WARD, ROYAL VINCENT, The Southern California Edison Co.; res., 870 No. Fair Oaks, Pasadena, Cal.

WARREN, J. S., Salesman, Westinghouse Electric & Mfg. Co., Bank of Commerce Bldg., St. Louis, Mo.

WATERS, HAROLD, Electrical Engineer, Otis Elevator Company; res., 325 Riverdale Ave., Yonkers, N. Y.

WHITAKER, JOSEPH H., Assistant Superintendent, Seattle-Tacoma Power Co., Seattle, Wash.

WILDIN, GEORGE WASHINGTON, Mechanical Superintendent, New York, New Haven and Hartford Railroad, New Haven, Conn.

WILSON, HUNTER T., Chief Electrician, Public Service Operating Co.; res., 114 E. 4th St., Belvidere, Illinois.

WILSON, JOHN SPICER, Testing Department, Bullock Mfg. Co.; res., 2710 Norwood Ave., Norwood, Ohio.

WOOD, ALBERT CARROLL, Consulting Mechanical Engineer, 819 Pennsylvania Building, Philadelphia, Pa.

WOOD, LELAND DURFEE, Sub-station Attendant, Edison Electric Illuminating Company of Brockton, Brockton, Mass.

WOODWARD, CHARLES VANDERBILT, Salesman, Westinghouse Electric & Mfg. Co., North American Bldg., Philadelphia, Pa.

YOST, VICTOR AUGUSTUS, Electrical Engineer and Contractor, Yost and Yost, 1 Central Ave., Ossining, N. Y.

ZEIENTZ, LOUIS, Transit Inspector, Public Service Commission, 1st District, 154 Nassau Street, New York City.

ZIMMER, LEO PHILIP, Chief Electrician, Bath Electric and Gas Light Co., Bath, New York.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before May 25, 1910.

9428 Davis, E. G., New York City.
9429 Gerhardt, R. B., Orient, Cuba.
9430 Kraps, L. J., Vallecito, Cal.
9431 Vaughan, F. A., Milwaukee, Wis.
9432 Clark, Wm., Boston, Mass.
9433 Davis, J. F., Youngstown, O.
9434 Kelly, J. Z., New York City.
9435 King, W. D., Peabody, Mass.
9436 Kline, H. W., Salt Lake City, Utah
9437 Stahl, W. W., Salt Lake City, Utah
9438 Thomas, G. B., Boston, Mass.
9439 Allen, O. F., New York City.
9440 Brown, A. A., New York City.
9441 Coffin, A. H., Boston, Mass.
9442 Crouse, R. C., Chicago, Ill.
9443 Fagan, W. M., Los Angeles, Cal.
9444 Forshund, C. F., Vallecito, Cal.
9445 Fowler, S. B., Boston, Mass.
9446 Gill, W. A., Honolulu, T. H.
9447 Haley, C. F., Mexico, D. F.
9448 Harris, F. W., Ronceverte, W. Va.
9449 Haseltine, W. E., Boston, Mass
9450 Hecker, R. E., Syracuse, N. Y.
9451 Hirt, W. A., Evanston, Ill.
9452 Jennings, N. L., Golden, Colo.
9453 Jutton, H. W., Hamilton, Can.
9454 Mansfield, A. P., Lynnfield, Mass.
9455 McClain, R. D., Greenville, S. C.
9456 Ovitt, F. H., Enosburg, Vt.
9457 Robles, C. E., Cartago, C. R.
9458 Reid, L. G., Chicago, Ill.
9459 Staffelbach, W. A., Chicago, Ill.
9460 Taylor, D. B., Troy, N. Y.
9461 Wilson, H. M., New York City.
9462 Wolfrum, C. A., Grace, Idaho.
9463 Adams, K. E., Boston, Mass.
9464 Bicknell, G. W., Boston, Mass.
9465 Bobst, J. A., Iowa City, Ia.
9466 Daniel, F. R., Indianapolis, Ind.
9467 Joseph, Geo., Bombay, India.
9468 Lorentz, F. S., Toston, Mont.
9469 Murphy, J. S., Morgantown, W. Va

9470 O'Reilly, T. W., Los Angeles, Cal.
9471 Royer, T. J., Aqueduct, Cal.
9472 Seybold, R., Pittsburg, Pa.
9473 Walsh, T. J., Houghton, Mich.
9474 Wortman, C., San Francisco, Cal.
9475 Berdon, A. E., W. La Fayette, Ind.
9476 Buchanan, A. S., Northfork, W. Va
9477 Flager, H. J., Red Lodge, Mont.
9478 Lucas, F. F., Atlanta, Ga.
9479 McCoy, H. A., Lowell, Mass.
9480 Miller, W. C., Jr., San Francisco, Cal.
9481 Morse, A. W., Rivers, Man.
9482 Mortensen, N. L., Milwaukee, Wis.
9483 Patterson, R. E., Tonkawa, Okla.
9484 Whitney, E. F., Seattle, Wash.
9485 Wynes, J. A., Canton, Ill.
9486 Davis, H. G., New York City.
9487 Fisher, C. M., Bozeman, Mont.
9488 Goodwin, C. K., Tuolumne, Cal.
9489 Philips, H. E., Pinawa, Man.
9490 Waldenfels, F. G., Chicago, Ill.
9491 Rakestraw, C. N., Provo, Utah.
9492 Robinson, R. W., Topeka, Kansas.
9493 Bohan, W. J., St. Paul, Minn.
9494 Brown, F. W., San Francisco, Cal.
9495 Childs, R. B., Col. Spgs., Colo.
9496 Gilbert, H. N., Chicago, Ill.
9497 Lange, E. C., Kewanee, Ill.
9498 Sage, M. W., Washington, D. C.
9499 Bruninga, J. H., Washington, D.C.
9500 Schneeberger, G. B., Cleveland, O.
9501 Jarvis, E. A., New York City.
9502 Johns, G. McD., St. Louis, Mo.
9503 Petrie, J. R., Mazatlan, Mex.
9504 Bale, L. D., Cleveland, Ohio.
9505 Barney, C. A., Kewanee, Ill.
9506 Dart, H. E., Hartford, Conn.
9507 Flores, R. R., Cananea, Son. Mex.
9508 Munning, A. P., Brooklyn, N. Y.
9509 Skoog, S. P., San Francisco, Cal.
Total 82.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at its regular monthly meeting held on April 15, 1910. Any objection to the transfer of these Associates should be filed at once with the Secretary.

JENS LUDWIG DIEMER-HANSEN, The Electricity Company, Ltd., Bangkok, Siam.

JAMES DELMAGE ROSS, Electrical Engineer, Seattle Municipal Light and Power Plant, Seattle, Wash.

JOHN HARISBERGER, Superintendent and Electrical Engineer, Seattle-Tacoma Power Company, Seattle, Wash.

WALTER SHERMAN MOODY, Designing and Executive Engineer, Transformer Department, General Electric Company, Pittsfield, Mass.

MORTON G. LLOYD, Associate Physicist, Bureau of Standards, Washington, D. C.

W. L. ABBOTT, Operating Engineer, Chicago Edison Company, Chicago, Ill.

Students Enrolled,—April 15, 1910

3621 Boggs, C. E., Wash. State College.
3622 Burgeson, J. A., Iowa State Coll.
3623 Dawson, C. A. W., Wash. State Coll.
3624 Gernandez, G., Univ. of Mich.
3625 Freeman, H. S., Cornell Univ.
3626 Gould, R. W., Univ. of Maine.
3627 Kaplan, E. V., Univ. of Minn.
3628 Knowles, B. E., Wash. State Coll.
3629 Leland, C. A., Jr., Univ. of Kans.
3630 Marston, W. R., Wash. State Coll.
3631 Raasch, F. A., Iowa State Coll.
3632 Richardson, E. A., Univ. of Wis.
3633 Richardson, L. T., Univ. of Wis.
3634 Skinner, B. C., Stevens Inst. Tech.
3635 Smith, H. E., Penna. State Coll.
3636 Springer, G. E., Univ. of Maine.
3637 Wallace, W. S., Cornell Univ.
3638 Albrecht, J. H., Univ. of Mich.
3639 Barenther, A. A., Rens. Poly. Inst.
3640 Bawser, C., Univ. of Kansas.
3641 Beck, V. S., Univ. of Minnesota.
3642 Benford, F. A., Jr., Univ. of Mich.
3643 Gates, H. C., Univ. of Mich.
3644 Gauss, W. F., Univ. of Michigan.
3645 Hustad, B. P., Univ. of Minn.
3646 Kiyohara, I., Wash. State Coll.
3647 Lehman, R. F., Univ. of Illinois.
3648 Montgomery, O. C., Univ. of Neb.
3649 Mullen, R. B., Univ. of Wash.
3650 Pearce, H. U., Univ. of Michigan.
3651 Peck, H., Montana State College.
3652 Phelps, A. S., Mass. Inst. Tech.
3653 Rodi, C. M., Univ. of Michigan.

3654 Rose, K., Univ. of Michigan.
3655 Seng, A. W., Kansas State Agr. Col
3656 Shepard, J. A., Rose Poly. Inst.
3657 Stein, A. L., Mass. Inst. Tech.
3658 Stokes, P. F., Rose Poly. Inst.
3659 Struve, M. L., Univ. of Nebraska.
3660 Vidro, E. F., Univ. of Michigan.
3661 White, V., Univ. of Nebraska.
3662 Young, H. N., Univ. of Cal.

Sections and Branches

University of Arkansas Branch

The University of Arkansas Branch held its regular meeting on March 15, 1910. Mr. H. C. Lamberton read a paper on "Block Signalling." Mr. C. A. Moreland reviewed recent technical publications. Mr. S.B. Graham followed with a paper on "Automatic Telephones."

At the next meeting, held on March 30, Professor G. E. Ripley addressed the members on "Blue Prints." Mr. W. B. Stelzner gave an abstract from a paper on "Protection of Insulators from Lightning and Power Arc Effects."

Armour Institute of Technology Branch

At the regular meeting of the Armour Institute of Technology Branch, held in Physics Hall, Armour Institute, on February 17, 1910, Mr. Albert F. Horton consulting illuminating engineer, of Chicago, read a paper on "Decorative Lighting." Mr. Horton discussed at length the requisites of good illumination. Methods of measuring light and the proper distribution of light were shown very effectively. The effect of different kinds of light, and the general characteristics of modern furniture and different types of fixtures, in their relation to the lighting of a room, were carefully considered. Problems of light and decoration were also taken up, as well as the correct proportioning of light and the concealing of lamps under unfavorable conditions. The difference between light for reading and light for general illumination was shown. All of the points discussed were effectively illustrated by a large number of lantern slides showing interiors more or less elaborately decorated. As each was presented Mr. Horton criticized it frankly, showing the good and bad points and how the lighting fixtures could be arranged to harmonize with the general scheme of decoration.

The next meeting of the Branch was held in Chapin Hall on March 24. A paper on "Hydroelectric Development" was read by Mr. W. J. Baer. Mr. Baer introduced his subject with an outline of the general considerations entering into the development of a water power, including cost of power, determination of capacity, and commercial prospects. He discussed the various conditions which affect the cost of erection of the plant. In conclusion he gave a brief description of a number of hydroelectric installations. Mr. Rosenthal led the discussion which followed and gave a talk on various types of dam construction.

Atlanta Section

On March 8, 1910, 22 members of the Atlanta Section were addressed by Mr. H. E. Bussey, on "Induction Motors and Rotary Condensers." The object of Mr. Bussey's paper was to show the relation between a synchronous motor and a rotating condenser. Owing to the wide use of the induction motor and its tendency to reduce the power factor of central stations, thereby limiting the generating capacity of the station, it is necessary to install in central stations or substations some form of apparatus which will counteract the effect of low power factor. Mr. Bussey pointed out in his paper that by the use of rotating synchronous condensers this difficulty could be almost entirely overcome. The paper was discussed by Messrs. Wood, Winn, Peck, Gordon, Wilder and Bonyun.

Baltimore Section

The March meeting of the Baltimore Section was held in the physical labora-

tory of the Johns Hopkins University, Baltimore, on March 11, 1910. Fifty-one members and visitors were present. Mr. Edwin Dreyfus presented a paper on " Low Pressure Steam Turbines ", which was well illustrated with lantern slides. Dr. J. B. Whitehead exhibited some of the new Edison storage batteries and gave the results of some tests.

The next meeting of the Baltimore Section was held on April 8. Mr. F. Darlington, of the Westinghouse Electric and Manufacturing Company, read a paper entitled " The Present State and Tendency of Steam Railway Electrification." Mr. Darlington showed lantern slides of the more important types of electric locomotives in use in the United States, and discussed the subject at length. He emphasized the importance of supporting the weight of the motor on springs and not rigidly on the axle beams, if high speeds are to be maintained.

Case School of Applied Science Branch

Eighteen members of the Case School of Applied Science Branch made an interesting tour of inspection early in March to electrical stations at Niagara Falls, Buffalo, Chicago and Milwaukee. The trip lasted for 10 days and was greatly enjoyed by those who made it.

The regular meeting was held on April 6, at which Mr. L. C. Doane delivered a lecture on " The Study and Design of the Series Current Relay." Mr. Doane spoke of the growing demand for automatic motor starters, and explained tests that he was making in connection with current-relays of exact design and performance. At this same meeting Mr. W. R. Waggonner gave a talk on some proposed remedies for electrolytic corrosion of water and gas pipes, and showed to what extent the methods of using insulating joints and of bonding to the regular current conductor were feasible.

Chicago Section

A joint meeting of the Chicago Section with the Electrical Section of the Western Society of Engineers was held on March 23, 1910, with Mr. George H. Lukes in the chair. A paper on " Diversity Factor in the Distribution of Light and Power " was read by Mr. H. B. Gear. Considerable discussion followed by Messrs. W. B. Jackson, W. L. Abbott, H. Almert, S. M. Bushnell, P. B. Woodworth, A. Bement, and F. F. Fowle.

Colorado State Agricultural College Branch

The Colorado State Agricultural College Branch was formally organized at its meeting held on March 4, 1910. The following officers were elected: President, E. J. Falloon; vice-president, Ralph E. Drake; secretary-treasurer, D. E. Byerley; executive committee, the president, secretary, and Professor F. A. De Lay.

At the meeting held on March 18, Mr. R. A. Mason gave an account of the tour of inspection of power plants in Colorado, made by the senior class of engineers, after which Professor De Lay addressed the members on the efficiencies, manufacture and use of the various types of incandescent lamps.

On April 1 Professor A. E. Bessey gave a description of the testing and installation of high-voltage transformers. Mr. Alfred Johnson described the three-wire system.

University of Colorado Branch

The members of the University of Colorado Branch met on March 16 to hear a debate between the electrical and mechanical societies. The proposition was: " Resolved, that a hydro-electric plant can deliver current to the City of Boulder more economically than a steam plant." Messrs. Metcalfe and McKinney took the affirmative side, and Messrs. Hall and Limprecht the negative. The judges were Messrs.

Brackett, Ham and Storrer. Both sides gave considerable data relating to the initial cost of plants and the cost of power. Each speaker was given a period of eight minutes and a rebuttal of five minutes.

Fort Wayne Section

Some of the less common types of switchboard instruments were discussed before the Fort Wayne Section on the evening of April 14, 1910, in a paper by Mr. J. J. A. Snook, entitled " Regulators and Special Switchboard Instruments." The greater portion of the paper dealt with the different types of voltage regulators, their requirements, location in the circuit, connections to the switchboard, and operation.

State University of Iowa Branch

This Branch held two meetings in March. On March 14 Mr. A. J. Lundquist abstracted Mr. H. L. Doherty's paper on " Development and Operation of Hydroelectric Plants." At the meeting of March 28 Mr. E. H. Bailey abstracted Mr. W. Lee Campbell's paper on " Modern Automatic Telephone Apparatus."

Ithaca Section

Mr. H. W. Fisher, of Pittsburgh, Pa., addressed the members of the Ithaca Section on March 18, 1910. Mr. Fisher's subject was " Products of an Up-to-date Cable Factory." Ninety members were present.

On Friday evening, April 15, Mr. George W. Nasmyth gave a lecture before 120 members of the Section on " High Frequency Phenomena." This lecture was preliminary to a more advanced lecture which will be delivered by Professor H. T. Plumb, of Purdue University, on May 6. Mr. Nasmyth's lecture, which was largely experimental, demonstrated the following: Spark discharges and transient phenomena; the singing arc; maintained high frequency effects; electric resonance; connection between wave length, velocity of electric waves and frequency; electric screening with high frequency waves, and, in general, electric oscillations of the order of 500,000 cycles per second.

University of Kansas Branch

The regular meeting of the University of Kansas Branch was held in Blake Hall, of the university, on February 23, 1910. Mr. Elbert Farber gave an account of his thesis work, " A Test on the Lincoln Center, Kansas, Power Plant." Mr. Glen Morris followed with a talk on " The Mercury Arc Rectifier and Its Application."

On March 16 Mr. R. R. Stewart, who formerly was with the Kansas City Power and Electric Lighting Company, gave a talk on " The Care and Calibration of Testing Meters and Integrating Wattmeters." There was some discussion.

At the meeting of March 30 Mr. V. A. Foster reviewed Professor W. S. Franklin's paper on " The Space Economy of the Single-phase Series Motor."

Lehigh University Branch

The regular April meeting of the Lehigh University Branch was held in the physical laboratory of Lehigh University on April 12, 1910. Three papers were presented. The first was by Mr. L. Dunning, on " Purification of Water", which described three methods of accomplishing this. First, by mechanical filtration; secondly, by chemical processes; and, thirdly, by electrolytic means. The electrolytic process by the use of ozone was dealt with in detail, together with the method of producing ozone.

In a paper entitled " Magnetos ", Mr. F. W. Haltermann discussed the principal types of magnetos now in use. There has been a great demand for this machine during recent years, owing to the increase in the manufacture of automobiles. A number of magnetos were exhibited by the speaker in the course of his remarks.

Professor Esty concluded the program with a talk on "Empirical Equations."

Lewis Institute Branch

Four hundred members of the Lewis Institute Branch were addressed on March 15, 1910, by Mr. Henry W. Lee, of the Collins Wireless Telephone Company, on the "Wireless Telephone." The lecture was limited largely to demonstration, the transmitting and receiving devices being installed in various parts of the building. Conversation was carried on with portable receivers and transmitters.

Los Angeles Section

The regular meeting of the Los Angeles Section was held on March 22, 1910. One hundred and twelve members and guests were present. Mr. E. F. Scattergood presented a paper on "Electric Power in the Construction of the Los Angeles Aqueduct." Messrs. Gardett, Lighthipe, Ballard, Benedict, Noble, and W. A. Ferguson, Secretary of the Mexico Section, took part in the discussion.

University of Maine Branch

The second meeting of the University of Maine Branch, since its reorganization, was held on April 6, 1910, with 20 members present, and Mr. A. T. Childs presiding. Professor W. K. Ganong discussed the conference of the professors of electrical engineering of the New England colleges with the representatives of the large manufacturing companies at Lynn, Mass.

Milwaukee Section

The first meeting of the Milwaukee Section was held in the club room of the Plankinton House, Milwaukee, on March 16, 1910. Mr. A. W. Berresford presided. Officers were elected as follows: Chairman, W. H. Powell; secretary, L. L. Tatum. A simple set of by-laws was adopted. Some discussion centered around the acceptance of enrolled Students as members of the Section. The general opinion, however, was that one of the most important objects of the Section should be the encouragement of the students and younger engineers to affiliate with the engineering bodies and that no financial consideration should be allowed to exclude them. A scheme of affiliation with the Engineers' Society of Milwaukee was adopted. The Engineers' Society maintains permanent quarters and has the use of a large meeting room once a month. An agreement was made whereby the Milwaukee Section will have the use of the society's rooms, and the staff of the society will take care of all clerical work, notices of meetings, etc. The meetings of the two societies are to be merged, the Section assuming charge of some meetings, presumably on electrical subjects, and the Engineers' Society taking charge of the others. The Engineers' Society assumes all the expenses of the Section except the entertainment of speakers, and charges a fixed yearly sum per member for this service. Thirty-six members were present at the meeting.

Minnesota Section

The Minnesota Section held a meeting at the office of the Twin City Rapid Transit Company, Minneapolis, on Monday evening, March 14, 1910. Mr. Charles A. Lang, of the Northwestern Consolidated Milling Company, Mr. W. H. Bovey, of the Washburn Crosby Company, and Mr. L. O. Gordon, of the General Electric Company, gave talks on "The Application of Electricity to Flour Mills." The papers brought out some interesting discussion by Messrs. Blossom, Frailey and Gibbs. Quite a number of flour mill engineers and officials were present.

Madison Section

The regular meeting of the Madison Section was held on March 1, 1910, in the Engineering Building, University of Wisconsin. About 50 members and visitors were present. The program consisted of a paper entitled "The Tungsten Lamp", which was presented

by Mr. M. D. Cooper, of the National Electric Lamp Association. For the benefit of those not familiar with the work done at the laboratory of the association, Mr. Cooper first gave a brief outline of the methods employed in carrying on the work. He explained how the efforts of the engineering department are divided along three lines; namely, research, technical engineering, and commerical engineering, and stated briefly the functions performed by each of these divisions, in this way giving his audience a general view of the methods employed by the association in the development of the high efficiency lamps. Mr. Cooper then took up his paper and discussed in detail the engineering problems which had been solved in bringing the tungsten lamp to its present high grade of efficiency. He then explained the processes used in the manufacture of the filaments, bringing out the difference between these processes and that used in the manufacture of carbon filaments. By means of lantern slides the results of numerous life tests of different types of lamps were shown. In all cases the superiority of the tungsten lamp was evident. Photographs were thrown on the screen showing carbon, tantalum and tungsten filaments which had been in service varying lengths of time. The photographs showed how the structure of the filament changed as the time of service increased. The tungsten filament, which at first had presented a practically smooth surface, became a series of small sections, crystalline in structure. This is entirely different from the appearance of the carbon filament after carrying current, and brings up a point of interest in connection with the handling of tungsten lamps. The tungsten filament when cold is very brittle, and on account of its extremely small diameter, very fragile, and after use it becomes much more fragile, owing to the irregularities in crosssection. To minimize the danger of breakage, therefore, the lamp should be handled only when the current is flowing, because at such time the filament is more pliable, on account of the heating effect of the current. In discussing the methods used to calculate the tension to which the filament must be subjected it was shown that the problem is very similar to the one met in the design of a transmission line. The form which the suspended filament assumes is that of the catenary curve, and therefore the equation of the catenary is used in calculating the tension. These calculations must be very accurate because the tension must be such that there is no danger of the filaments coming in contact with each other when elongated by heating, and, also, there must be no possibility of the filament being broken by the increased tension due to contraction on cooling. On account of the delicate nature of the filament, this problem is one much more complex than might be imagined by those who have not given it study. Mr. Cooper then took up briefly the effect on the central station of the introduction of the tungsten lamp. By means of curves he showed that a station with a comparatively light motor load during the day and a heavy lighting load in the afternoon and evening would be forced to operate at a loss if the lighting installations were all changed to tunsten lamps of the same aggregate candle-power, provided the station had been operating at only a reasonable rate of profit before the change was made. To compensate the generating company for this loss due to the introduction of the high efficiency lamps the speaker advocated a schedule of rates, somewhat similar to the Doherty rate now in use in some cities, which would include a fixed charge in proportion to the maximum candle-power installed, and a comparatively low charge per kilowatt-hour for actual power used. In the discussion which followed several points were brought out regarding the relation of the tungsten lamp to the central station. It was shown how the changes from low efficiency to high efficiency lamps have

in no instance been complete, and that the changes have been gradual, thus affording the central station opportunity to develop business along other lines. Another point was that in many instances the consumer in installing the high efficiency lamps increases the total candle-power of the installation to such an extent that the change in amount of power used is comparatively small. It was also suggested that as the high efficiency lamps can be manufactured for voltages as high as 220 volts, it may be possible at some future time, when this class of lamp has been brought to a little higher degree of efficiency, that the distribution systems will be made 220-440-volt, three wire, instead of the present 110-220-volt, three wire, thus effecting a large saving in copper losses and in cost of construction of the distributing system.

UNIVERSITY OF MISSOURI BRANCH

The regular meeting of the University of Missouri Branch was held on February 28, 1910. Messrs. R. W. Curran and V. L. Board presented Mr. H. L. Doherty's paper on "Developments and Operation of Hydroelectric Plants." In the discussion, Mr. J. D. Bowles commented on the descriptive paper by Mr. W. A. White, on "Water Powers of the United States," and particularly on the statement that water powers were being taken up and held without development. The statement was made that in California the majority of the water powers had been taken up and that only a very small percentage had been developed.

On March 21 certain resolutions were adopted relating to the affairs and conduct of the Branch. Mr. E. W. Stapf then presented an abstract of Professor D. C. Jackson's paper on "The Application of Electrical Power to Industrial Establishments." Mr. C. R. Surface abstracted Mr. Charles T. Main's paper on "Central Stations *versus* Isolated Plants for Textile Mills." In the discussion of Mr. Main's paper there was some criticism of the use of compound engines for textile plants where exhaust steam could be used for heating processes.

The topic of discussion at the meeting of the Branch on March 28 was "The Choice of Work Immediately After Graduation." The speakers were, H. B. Shaw, on "Graduate Study"; A. E. Flowers, "Apprenticeship Courses"; J. A. Whitlow, "Central Station Work." Professor Shaw spoke as follows:

"The University of Missouri is undergoing the transition from the old four-year technical course to a more strictly professional three-year course, it having been decided to require two years of study in the College of Arts and Science for entrance to the engineering courses, and three years of engineering study, so that graduates will have had altogether five years of college training. The professional degrees of C.E., E.E., M.E., and Ch.E., will be given to graduates. In former years the professional degree has been granted to holders of the bachelor's degree after the presentation of a thesis and the completion of a certain amount of study in absentia. This practice has been discontinued, and graduates holding either bachelors' or professional degrees must take work in residence, except that students already enrolled for graduate work in absentia will be allowed to continue. The requirements for graduate work in residence and the degree to be given have not yet been decided upon except that the holders of bachelors' degrees may obtain the professional degree after one year's study. One form of such advanced work is in connection with the fellowships offered by the engineering experiment station. Three such fellowships have been established and two of them filled for the year 1909-1910, the purpose being to carry out experiments or collect information that will be of use to the state. Some of the problems that have been proposed for this year are the

lighting of country homes, the water supply for country homes, and a study of methods of testing lubricating oils. Other problems that may be taken up are water power and water supply in Missouri, and the supply of heat to buildings."

Professor Flowers described the work of apprentices in the larger industrial establishments and the usefulness of the training afforded there in giving in a short time a vast amount of experience. He stated that the willingness of the managers of these establishments to devote so much effort to the training of young men was that they realize the necessity of training men to fill their own positions; that the proper training of the men of the organization is equally as important as providing new physical equipment.

Commenting on this phase of the subject, Professor Shaw told of the answer made by Mr. Andrew Carnegie to some visitors who asked whether he would prefer to start anew with his furnaces and works, without his men, or to start with his organization of men intact, without his furnaces and works. Mr. Carnegie unhesitatingly replied that he would prefer to keep his organization of men intact.

Mr. Whitlow described the work in the different departments of a large central station and the opportunities in each for the technically trained men.

Montana State College Branch

Mr. Charles L. Zahm, chief engineer of the Interstate Independent Telephone Company, lectured before the Montana State College Branch on March 15, 1910. The subject of Mr. Zahm's lecture was "Automatic Telephone Systems." A set of three telephones was set up for the purpose of illustrating the lecture, and a number of sets of blue prints were passed around the audience. Mr. Zahm gave a history of the development of the automatic telephone, and explained the principles of its operation. Fifty-two members attended the lecture.

University of Nebraska Branch

This Branch held its fifth meeting for the year 1909–1910 in the lecture room of the electrical engineering department of the university on Tuesday evening, March 8, 1910. Mr. Leonard E. Hurtz, manager of the Lincoln Telephone and Telegraph Company gave a review of the Institute papers entitled, "A Study of Multioffice Automatic Switchboard Telephone Systems", and "Modern Automatic Telephone Apparatus." Parts of old and new automatic telephone equipment were presented for inspection.

The following officers were elected at the meeting of the Branch held on April 1, 1910: Chairman, Professor George H. Morse; secretary, Professor V. L. Hollister.

On April 5 the Branch held a joint meeting with the mechanical engineers and the Engineering Society of the University of Nebraska. Professor Hollister made a few preliminary remarks regarding the benefits of the society to the students in electrical engineering. Dean C. R. Richards was then introduced, and gave a stereopticon lecture on "The Steam Turbine." Views illustrating the theory and construction of modern steam turbines, and models of early inventors, were thrown on the screen. The paper dealt with the commercial turbine engines now on the market, and the constructional details. An enthusiastic audience of 75 members attended the lecture.

New Hampshire College Branch

Instead of the regular meeting of the New Hampshire College Branch, the members attended a lecture on March 30 by Dr. Frank A. Davis, on "Sanitation from the Standpoint of the Electrical Engineer." Dr. Davis is an alumnus of the New Hampshire College, and for the past few years has been particularly interested in the use of the X-ray treatment of disease. He described many methods by which

electricity is used for sanitation purposes illustrating many features by means of lantern slides. About 40 members and visitors were present.

North Carolina College of Agriculture and Mechanics Arts Branch

The first meeting of this Branch was held on March 29, 1910. The following officers were elected for the ensuing year: Chairman, Professor William Hand Browne, Jr.; secretary, E. B. Moore; treasurer, I. N. Tull. The following Institute papers were discussed: "Electric Mine Hoists", by D. B. Rushmore and K. A. Pauly; discussed by W. H. Browne, Jr., and F. M. Black; "Large Electric Hoisting Plants", by Wilfred Sykes; discussed by C. R. Jordan and I. N. Tull.

Ohio State University Branch

The annual election of officers of the Ohio State University Branch took place at the meeting of the Branch held on March 17, 1910. The following were elected: President, H. W. Leinbach; vice-presidents, E. E. Eby, A. L. Schieber, F. A. Kendig; secretary-treasurer, E. J. Pratt; corresponding secretary, F. L. Snyder.

Oregon Agricultural College Branch

Owing to the Easter recess the March meeting of this Branch was postponed to April 4, 1910. The subjects discussed were the protection of insulators against lightning, and electrolytic rectification. Mr. L. C. Nicholson's paper on "A Practical Method of Protecting Insulators from Lightning and Power Arc Effects" served as a basis of the first subject. The discussion was led by Professor T. M. Gardner, and was accompanied by an exhibition of various forms of lightning arresters. The second subject, which constituted the fourth paper of a series on electrochemistry, was presented by Messrs. F. A. Sorenson and W. Weniger, and consisted of a discussion and an experimental demonstration of various forms of electrolytic and solid-contact rectifiers, together with an account of the use to which these rectifiers have been put to date. There was a large attendance and the meeting was a very successful one.

Pennsylvania State College Branch

On March 3, 1910, Mr. W. M. Skiff, assistant chief engineer of the National Electric Lamp Association, gave an illustrated lecture before the Pennsylvania College Branch on the manufacture of incandescent lamps, tracing the process from the beginning to the finished product. At the same meeting Mr. H. H. Geary, of the Incandescent Lamp Company spoke on the duties of the commercial engineer and the opportunities offered in the illuminating engineering field.

On March 4, 1910, Mr. J. J. Gibson, of Philadelphia, addressed the members on the organization and management of sales departments.

At a meeting held on March 16 Dr. J. Franklin Meyer, of the Westinghouse Lamp Company, Bloomfield, N. J., spoke on the problems encountered in lamp manufacturing, with special reference to the research side.

Philadelphia Section

The Philadelphia Section held a meeting on March 14 in conjunction with the Illuminating Engineering Society, at which 154 members of the two organizations were present. The following papers were presented: "The Generation System of an Electric Lighting Company", by A. R. Cheyney; "Distribution", by D. F. Schick; "Electric Lighting Within the Consumer's Premises", by Harold Calvert. The papers were discussed by Messrs. E. P. Hyde, Preston S. Miller, W. C. L. Eglin, E. F. Northrup, Harold Calvert, H. A. Hornor and H. C. Snook.

Mr. F. W. Kelley, general manager of the Helderburg Cement Company, Albany, N. Y., was the guest and speaker at the meeting of the Section on April 11. Mr. Kelley spoke on "The Use of Electricity in the Manufacture of Cement." The subject was one of much interest and evoked considerable discussion. Among those who took part in the discussion were, Messrs. Drake, Porter, Sanville, Batchelder, Hoadley, Green, Patterson, Stevens, McLeod, and Kelley.

Pittsfield Section

The third annual dinner of the Pittsfield Section was held at Hotel Wendell on the evening April 7, 1910. Chairman H. W. Tobey presided as toastmaster. Among the musical features were a number of vocal solos, a cornet selection, and a general chorus by the members of the Branch. The speakers were Mr. Thomas D. Lockwood, manager of the patent department of the American Telephone and Telegraph Company, and Mr. Ralph W. Pope, Secretary of the Institute. In his introductory remarks Chairman Tobey referred briefly to the past history of the Pittsfield Section and its remarkable growth since it was organized in 1904. The membership at that time numbered about 17, while it now has 250 members. The attendance at the meetings has increased from an average of 25 per meeting in 1904-1905, to an average of 134 during the present season. Mr. Tobey then introduced Mr. Lockwood, who spoke at considerable length on "Early Electrical Engineering." The next and last speaker was Mr. Pope, whose subject was "Achievements in the Electrical Art."

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The regular meeting of the Section was held on April 14, and 180 members and visitors gathered to hear a lecture by Dr. C. P. Steinmetz, on "The Industrial Importance of Luminescence." Dr. Steinmetz went very thoroughly into the subject of light, from both chemical and electrical points of view. A number of experimental demonstrations added greatly to the interest of the lecture.

At this meeting there were on exhibition a number of the original manuscripts of Samuel F. B. Morse, the inventor of the telegraph, bearing on developments in telegraphy in 1845. The manuscripts are the property of Mr. Edward Linden Morse, of Stockbridge, Mass., the inventor's youngest son, who kindly lent them to Mr. J. Franz, a member of the Pittsfield Section, for exhibition at the meeting.

Portland Section

The Portland Section held its regular meeting in the assembly hall of the new Electric Building, Portland, Oregon, on March 22, 1910. An interesting paper was presented by Mr. O. B. Coldwell, entitled "Efficiency Tests of a Water-Wheel Unit." The paper contained much valuable data which had been obtained from a long series of complex tests. This was the first meeting held by the Section in the Electric Building, which is the new home of the Portland Railway, Light and Power Company, and the attendance reached the highest point in the year, 87 members and visitors being present. Arrangements are being made by the executive committee to establish permanent quarters in the Electric Building, and to have an assistant secretary keep the room open during certain hours each day.

Purdue University Branch

At the meeting of the Purdue University Branch on February 22, 1910, Mr. W. T. Small, an instructor in the school of electrical engineering, addressed the members on "The Value of Apprenticeship Courses." Mr. Small gave an outline of how the courses are conducted, and the advantages to be derived from them by electrical engineering graduates. He described the courses offered by the Westinghouse, General Electric, and Allis-Chalmers

companies, and the work in each department. In the discussion which followed, Professor Topping summarized the advantages of the apprenticeship course. Among the disadvantages he mentioned a prevalent lack of discipline. Mr. C. E. Schutt and Mr. W. T. Heck related their personal experience in apprenticeship work. Mr. Broadwell told of his experience in hotel wiring in Florida. Professor Harding discussed the opportunities offered by the General Electric Company.

On March 15, Professor H. T. Plumb, of the electrical engineering department, delivered an address on "Lightning Arresters." Professor Plumb has done considerable work in this line, and he showed an intimate knowledge of the subject. In addition to exhibits of a number of lightning arresters, lantern slides were used to show various methods of protecting buildings and equipment from lightning. A description was then given of some of the phenomena of lightning discharges, demonstrated by apparatus set up for producing artificial lightning. Professor Plumb showed that although it is comparatively easy to protect a building from lightning, it is much more difficult to protect power lines and electrical apparatus. This is further complicated by the meagre knowledge available regarding the exact nature of lightning.

Mr. H. B. Marsh, of Indianapolis, an alumnus of Purdue of the class of '96, addressed the meeting of the Branch held on April 5. His subject was "Engineering and Cost Keeping." The first part of Mr. Marsh's address treated of a student's technical training while in the university. He stated that a college training, combined with good sense, was sufficient equipment to give a college man pre-eminence in his profession, but that the latter was the most important factor of the two. In support of this statement he cited many instances of eminent engineers who had not had the advantage of a college training. In the latter part of his address Mr. March emphasized the importance of a system of cost keeping. He gave a detailed outline of the system and explained its practical working. Many printed forms used in the system were shown and described.

Rensselaer Polytechnic Institute Branch

The members of this Branch made a tour of inspection to the power houses of the Schenectady Power Company, located at Johnsonville, N. Y. and Schagticoke, N. Y., on March 26, 1910. The morning was spent in inspecting the power station at Johnsonville, which is located at one end of a spillway dam constructed primarily to provide additional storage water for the larger power station at Schagticoke. This larger power station and the pipe line leading to it were inspected in the afternoon. This opportunity to inspect one of the most modern hydroelectric developments in this country was of great benefit to the members of the Branch.

St. Louis Section

The March meeting of the St. Louis Section was held in the rooms of the Engineers' Club, St. Louis, on March 9, 1910, Mr. A. H. Timmerman presiding in the absence of Chairman Langsdorf. After the usual routine business was transacted, the paper of the evening, "Alternating-current Motors for Crane, Hoist and Elevator Service", was presented by Mr. Oddgier Stephenson, of the Wagner Electric Company. The paper was illustrated by lantern slides. Mr. Stephenson first described the characteristics of the cumulative compound motor which is used for elevator service in direct-current work, and then showed slides of alternating-current motor characteristics and how these could be modified to suit the conditions of service to which the motors would be adapted.

On the evening of April 9, the St. Louis Section, in coöperation with the St. Louis Section of the A.S.M.E. and the Engineers' Club of St. Louis, held a joint meeting in the rooms of the Engineers' Club. The following papers, read at the joint meeting of the A.I.E.E. and the A.S.M.E. at New York on April 12, were presented in abstract and discussed: "Economy of the Electric Drive", by A. L. DeLeeuw, abstracted by E. L. Ohle; "Economic Features of Electric Motor Applications", by Charles Robbins, abstracted by F. A. Berger; "Mechanical Features of Electric Drive in Machine Shops", by John Riddell, abstracted by Oddgier Stephenson; "Motor Applications to Machine Tools", by Charles Fair, abstracted by A. S. Langsdorf. The papers were discussed by Messrs. Goss, Fish, Timmerman, Beardsley, Langsdorf Hibbard, Bryan, and Morse. Ninety members of the various societies were present.

San Francisco Section

At the meeting of the San Francisco Section on March 25, 1910, Mr. C. F. Elwell read a paper entitled, "The Poulsen System of Wireless Telephony and Telegraphy." The paper dealt largely with the relative advantages of the Poulsen system over other systems. Those who may be interested in the subject will find the paper published in the *Journal of Electricity, Power and Gas*, issue of April 2, 1910.

Schenectady Section

Mr. C. L. Straub, of the Loomis-Pettibone Company, New York City, was the speaker at the regular meeting of the Schenectady Section held in Kinum Hall on March 15, 1910. The subject of Mr. Straub's talk was "Gas Producers and the Internal Combustion Engine." As an introduction to his remarks, Mr. Straub gave comparisons of the work done by gas engines in various parts of the world. He then took up the question of fuel consumption, comparing the cost of fuel for gas engines with that for operating steam engines. The development of the gas producer was carefully traced from 1878 to the present time. Many interesting illustrations were shown and the advantages and disadvantages of the various types of gas producers were discussed at considerable length. The latter part of the address was given over to gas engines using producer gas. Mr. Straub showed a number of illustrations of high-power gas engines used in the United States and in foreign countries. He explained the nature of the work done in each plant and gave a good general idea of the cost of operation. The attendance at the meeting numbered 150 members.

On March 29 Dr. C. P. Steinmetz delivered a lecture before the Section on the subject of "The Industrial Importance of Luminescence." Dr. Steinmetz briefly traced the development in the art of illumination from the earliest time to its present state of perfection. He showed the effect of temperature and frequency on visible radiation, or light, and the resulting changes in color. Many interesting experiments were shown with various elements and compounds for the production of light of varying brilliancy and colors. He stated that in the electrical field there are two possibilities. First, the use of gases as radiators by having them conduct the electric current. Secondly, the use of electrode vapor as found in the arc stream. Gases, however, are extremely poor conductors. Of the gases which have been investigated, nitrogen gives the best efficiency, but it is not as good as the tungsten lamp, although it surpasses the gas flame or ordinary in-incandescent lamp. The three materials giving a light efficiency much higher than can be obtained by incandescence are mercury, calcium and titanium. These materials, as well as the gases already referred to, were discussed in detail. In conclusion Dr. Steinmetz made the statement that we are only at

the beginning in the field of luminescence, especially on the electrical side. On the chemical side much has been accomplished by the Welsbach mantel.

At the meeting of the Section held on April 12 Dr. A. E. Kennelly, professor of electrical engineering at Harvard University, gave a talk on "Wireless Telegraphy and Telephony." Dr. Kennelly is a recognized authority on this subject, and his lecture was one of the best of the season. He did not touch upon the different systems in operation, nor upon the various inventions in the development of commercial wireless telegraphy and telephony as in use to-day, but confined his remarks to an explanation of the laws governing all systems. He pointed out defects and errors in early experiments, and improvements and corrections that have been made. In simple terms he explained the action at the receiving station of a wireless telegraph system, comparing it to single commutator bar in a generator in which the moving field is a succession of magnetic flux lines produced by the progression of ether waves. Dr. Kennelly expressed the belief that it will be possible in the near future to arrange apparatus so that interferences by crossing of messages may be satisfactorily prevented. In conclusion he pointed out that the commercial introduction of wireless methods must be slow because it means a revision of existing conditions and the abandonment of much valuable material now in use. Dr. Kennelly had an enthusiastic audience, and was greeted with a round of applause at the close of his remarks.

Seattle Section

An address on "Gas Engine and Electrical Equipment of the Gary Steel Plant" was delivered by Mr. R. H. Stevens before the members of the Seattle Section on March 19, 1910. Mr. Stevens was erecting engineer in charge of the engine equipment at Gary, and had in his possession a large number of lantern slides which he used to illustrate his address. Those taking part in the general discussion which followed were, Messrs. Miller, Magnusson, Thursk, Evans, and Dickson.

Syracuse University Branch

Mr. W. Lee Campbell's paper on "Modern Automatic Telephone Apparatus" was presented at the meeting of the Syracuse University Branch held on April 14, 1910. The paper was read by Mr. O. H. Bishop, and the discussion which followed dealt particularly with the relative costs of operation and maintenance of the automatic and manual systems.

Toledo Section

At the regular monthly meeting of the Toledo Section, held on March 31, 1910, the members were addressed by Mr. R. Havlicek, who gave a talk on "Electric Welding." The structure and handling of electric welders was explained in detail, each point being illustrated by blackboard sketches. The commercial advantage of electric welding lies in the rapidity with which the operation may be accomplished. Incidental to electric welding is the feature that the current heat will properly prepare the parts, thus eliminating the usual forging expense of shaping the parts and fluxing. Again, there is the heat economy of using the welding heat locally, which permits the finishing up of parts very close to the point of juncture. Many specimens were exhibited of electric welds in rings, tubes both rectangular and circular, rods, bars and sheets, not only in wrought iron, but in brass and copper.

Toronto Section

Mr. Jens Orten Boving, of London, England, was the guest of the Toronto Section at its regular monthly meeting held at the Engineers' Club, Toronto, on March 18, 1910. Over 100 members and visitors were present. Prior to the meeting a number of the members met at the St. Charles Café for luncheon.

Mr. Boving presented a paper entitled "Some Notes on Two Hydroelectric Power Plants in Sweden." The paper was particularly interesting in view of the fact that the hydraulic end of both these plants was designed by Mr. Boving. The paper was in two distinct sections; one covering the Gullspang power plant, being typical of a low head power development, and the other with the power plant at Trollhattan, this being typical of the high head power development. This latter plant development was undertaken and carried out by the Swedish Government. Mr. Boving spoke at length on the design of these two plants, and illustrated his paper throughout with an excellent series of slides. Both installations show radical design in several features. An interesting discussion followed the reading of the paper, in which the following gentlemen participated: Messrs. R. G. Black, K. L. Aitken, C. B. Smith, A. L. Mudge, Munroe, Corns, Pullan, and Bucke. Arrangements were made for two meetings in April; the first to be devoted to the subject of industrial power, at which John C. Parker, of Rochester, N. Y., was to be the speaker, and the other to be devoted to lightning phenomena, and to be addressed by Mr. E. E. F. Creighton, of Schenectady, N. Y.

Washington Section

On March 29, 1910, a joint meeting was held by the Washington Section and the Washington Society of Engineers. The speaker was Professor J. B. Whitehead, of Johns Hopkins University, Baltimore, who presented a paper on "Steam Railway Electrification." Dr. Whitehead pointed out that the adoption of electrification depends on both the physical conditions and the cost. Out of a total railroad mileage in this country of 220,000 miles, only about 1,000 miles have thus far been electrified. This includes the terminals and tunnel trackage in New York, Baltimore, and St. Clair and Cascade tunnels. The advantages of electric operation include speed, comfort, acceleration, tractive effort and headway. On the New York City elevated railroads electrification resulted in a 50 per cent increase in capacity. Terminal, suburban, express and freight service were treated separately, with consideration of the conditions affecting each. In each case electric operation is not only possible, but under advantageous conditions decidedly preferable. The great advantage of electric operation is the centralization of power generation, while its weakest feature is the transmission of power, for this failing, operation must shut down. The relative dangers of the two systems were considered. In referring to costs, Dr. Whitehead stated that the item of transportation, which is the main point of difference in the two systems, is about 56 per cent of the total cost of operation. From a consideration of the different items it was shown that where 10 or more trains were operated daily, a saving of 20 per cent of the cost could be effected under this heading by electrification. The different methods of electrical operation were next considered, direct current at 600 volts being the most common. Most alternating-current equipment is for single-phase, series, commutator motors, although at Cascade Tunnel of the Great Northern Railway, three-phase induction motors are used. Nearly 1,000 miles of road are being operated with alternating current, although the Washington, Baltimore and Annapolis Railroad recently abandoned this for direct current at 1,200 volts. The great advantage of alternating current lies in transmission at high voltage a transformer in the locomotive serving to reduce the working voltage. Substations can therefore be widely separated, and copper costs also kept down. Line voltage as high as 15,000 volts has been used in this way.

Washington University Branch

The members of the Washington University Branch met on March 18,

1910, for a general discussion on the application of electricity for industrial power purposes. The program consisted of abstracts by local members of papers published in various technical journals. Among those who took part in the discussion were, Messrs. Langsdorf, Nance, Lane, Cheney, Kantorwitz, Couper and Bradt.

Worcester Polytechnic Institute Branch

One hundred and fifty members and their friends attended the regular meeting of this Branch on March 24, 1910, and heard a talk by Mr. J. M. Nelson, on "The High-Tension System of the Connecticut River Transmission Company." Mr. Nelson, who is resident engineer for this company, first gave consideration to the generating station, showing a number of lantern slides of the power station located on the Connecticut River near Vernon, Vt., and the equipment contained therein. In discussing the transmission line a number of views were shown of the towers used by the company to carry the double set of wires. These towers are of steel construction, averaging 35 feet in height, carrying the wires at the vertices at a triangle of six feet on a side. Views were also shown of the spans at West Boylston, where special construction is used, and the arrangement of insulators was explained. The substations on the line were next taken up, that at Clinton receiving special attention. In conclusion, Mr. Nelson described briefly the distribution system in Worcester, explaining the principal features, and the difficulties which had been encountered during its installation.

Semi-Annual Meeting of American Institute of Chemical Engineers, June 22-24, 1910

The summer meeting of the American Institute of Chemical Engineers will be held at Niagara Falls, N. Y., June 22, 23 and 24, 1910. One of the features of the meeting will be visits to the chemical industries in the vicinity of Niagara Falls. A program of papers is being arranged by the committee on meetings.

Unit Coal and the Composition of Coal Ash

"Unit Coal and the Composition of Coal Ash," by S. W. Parr and W. F. Wheeler, is issued by the Engineering Experiment Station of the University of Illinois as Bulletin No. 37. By unit coal is meant the organic material which is involved in combustion, as apart from the mineral constituents which, in their natural state, enter into the composition of all coals. From the experiments described in the bulletin, it appears that when similar cases are compared, the variations in composition are chiefly in the extraneous matter; that for a given district, and more especially for a given mine, the value of the unit coal is practically constant. The heating value of the actual coal may vary considerably, but when the portion of the whole which is not coal is eliminated, the resulting material is of constant value.

Tables exhibit the thermal and chemical properties of coals, chiefly from Illinois, but also from other portions of the United States. Attention is called to the necessity of careful methods in determining the ash content. Certain districts, especially in Illinois, contain a peculiarity in the ash composition, heretofore overlooked, *viz.*, the existence of calcium carbonate in sufficient quantity to make it advisable to modify the usual ash determination to account for this constituent, which may occasionally be met to the extent of 5 or 6 per cent of the total weight of the coal.

Copies of Bulletin No. 37 may be obtained gratis on application to

W. F. M. Goss
Director of the Engineering Experiment Station University of Illinois, Urbana, Illinois.

Personal

Mr. A. J. A. Kean has been appointed chief operating engineer to the Guanajuato Power and Electric Company, Guanajuato, Mexico.

Mr. Silas Taber, formerly with the Moravian Electric Light, Heat and Power Co., Moravia, N. Y., is now on the staff of Jordan's Ltd., Sydney, N. S. W.

Mr. Carl E. Johnson has succeeded Mr. W. W. Piddington as general manager of the U. S. Electric Manufacturing Company, of Los Angeles, Cal.

Mr. L. Clyde Chatfield has accepted a position with the Edison Electric Illuminating Company, of Brooklyn, as foreman of electric construction.

Mr. Charles H. Keel, of the General Electric Company, Schenectady, N. Y., has been transferred from the testing department to the patent department.

Mr. W. C. Chappell has resigned from the British Columbia Electric Railway Company to accept a position with the Western Canada Power Company, Vancouver, B. C.

Mr. Elmer B. Severs has given up his position with the Wilkesbarre Gas and Electric Company to enter the engineering department of J. G. White and Company, New York City.

Mr. E. G. Howard, formerly general superintendent of the Pensacola Electric Company, has become associated with the Chicago office of the General Electric Company.

Mr. Charles R. Riker was recently appointed on the editorial staff of *The Electric Journal*. Mr. Riker will give special attention to commerical engineering subjects.

Mr. A. L. Kenyon, who for nine years has been chief engineer of the Empresas Electricas Associadas, Lima, Peru, S. A., has resigned his position to return to the United States.

Mr. J. B. Christy has resigned his position with the General Electric Company to become superintendent of transmission with the Interstate Light and Power Company, Galena, Ill.

Mr. R. L. Clift has resigned as commerical engineer for the Electric Supply Company, Memphis, Tenn., on account of his health, and has removed to his farm near Cincinnati, Ohio.

Mr. Harry Austin Yoe has left the General Electric Company, Schenectady, N. Y., and is now with the Washington, Baltimore and Annapolis Electric Railway Company, at Odenton, Md.

W. S. Barstow and Company announce the removal of their Portland, Oregon, office from the Failing Building to the Electric Building, corner Seventh and Alder Streets.

Mr. William C. Getz, electrical assistant, signal service at large, has left Fort D. A. Russell, Wyo., for Fort Riley, Kansas, where he will install a target range system for the signal corps.

Mr. J. R. Clark left the superintendent's office of Barber-Coleman Company, Rockford, Ill., on March 19 to take charge of the cost department of the General Fireproofing Company, Youngstown, O.

Mr. E. C. Bacot, formerly chief electrician of the Great Northern Power Company, and later with the Central Colorado Power Company, is now associated with the H. M. Byllesby Company, Chicago, Ill.

Mr. T. H. Amrine has resigned as associate in the Engineering Experi-

ment Station of the University of Illinois, and is now in the development laboratory of the General Electric Company at Harrison, N. J.

MR. R. B. MATHEWS, engineer with the Board of Fire Underwriters of the Pacific, recently changed his headquarters from Seattle to San Francisco, with headquarters in the Merchants' Exchange Building.

MR. E. GUNTER, formerly with the Winnebago Traction Company, Oshkosh, Wis., has recovered from a long illness, and is now with the American Smelters Securities Company, Santa Barbara, Chihuahua, Mexico.

MR. W. S. JOHNSON resigned his position with the Pacific Light and Power Company, Los Angeles, Cal., on March 1, and is now in the employ of the Otis Elevator Company, 88 First Street, Portland, Oregon.

MR. F. D. BROWN accepted on March 1 the position of chief engineer and superintendent of the Aberdeen Railway Company, Aberdeen, S. D. The company will build 4½ miles of street railway this summer.

MR. MEHRING V. EARDLEY has been transferred from the switchboard inspection department of the General Electric Company, Schenectady, N. Y., to the construction engineering department of the Boston office.

MR. R. NEIL WILLIAMS has left the General Electric Company to establish the International Technical Bureau, with offices in New York, Paris and Berlin. Mr. Williams is at present in Berlin, Dornbergstr. 3, II.

MR. F. J. RICKEY, for several years connected with the plant department of the Cincinnati Bell Telephone Company, has accepted a position with the Central Union Telephone Company, as manager, at Portsmouth, Ohio.

MR. JOSEPH D. SHAW, electrical and mechanical engineer of the Fountain-Shaw Engineering Company, Houston, Texas, has changed his address to the Andrews Building, Dallas, Texas, where his firm now has its principal office.

MR. F. G. HALDY, former superintendent of the chain block and electric hoist department of the Yale and Towne Manufacturing Company, Stamford, Conn., is now with the Imperial Electric Company, of Akron, Ohio, as sales engineer.

MR. CHARLES S. CLIFFORD, who for a number of years has been connected with the Buffalo office of the General Electric Company, has been transferred to the industrial department of the company at 30 Church Street, New York City.

MR. PERCY A. CHAPMAN, until recently connected with the mechanical department of the Public Service Railway Company, Newark, N. J., has taken a position with the Boston Elevated Railway Company, in the electrical engineer's office.

MR. R. W. CRYDER, formerly with the Westinghouse Electric and Manufacturing Company at Pittsburgh and New York, and later with the Guanica Centrale, Porto Rico, has again joined the Westinghouse company, in the Boston office.

MR. JAMES O. SPEAR, JR., who recently left the Carter and Gillespie Electric Company, of Atlanta, will hereafter represent the Fort Wayne Electric Works in the Charlotte, N. C. district, with offices in the Realty Building.

MR. W. GEALE HEWSON, formerly engaged on railway work at New York City and Pittsburgh, for the Westinghouse Electric and Manufacturing Company, has joined the staff of Smith,

Kerry and Chace, consulting engineers, Toronto, Ont.

MR. RAY OLIPHANT, after serving several years in the transformer department of the General Electric Company at Schenectady and Pittsfield, has been transferred to the supply department of the Chicago office, as transformer specialist.

MR. L. B. WOODWORTH, who for some years has been electrical engineer with the New Heriot Gold Mining Company, has been transferred to the consulting mechanical engineering department of H. Eckstein and Company, Johannesburg, Transvaal, S. A.

MR. PAUL F. THAYER resigned on January 1, 1910, as electrical engineer of the Hydroelectric and Gas Company, Warren, O., to accept the appointment of secretary and treasurer of the Youngstown Armature and Construction Company, Youngstown, O.

MR. C. A. CHASE, who for the last four and a half years has been chief engineer of the Mexican General Electric Company, Mexico City, has been transferred to the Boston office of the General Electric Company, in the mill power department.

MR. H. W. YOUNG has resigned as sales manager of the Central Electric Company to accept the appointment of president of the Delta Star Electric Company, Chicago, Ill., a new company manufacturing a line of high-tension specialties of its own design.

MR. E. W. GOUGH has been appointed assistant to the general manager of the New York and Queens Electric Light and Power Company, Long Island City. Mr. Gough was formerly with J. G. White and Company as electrical superintendent, at Pottsville, Pa.

MR. L. R. KRUMM has been transferred from San Francisco to the office of the chief signal officer, Washington, D. C., for engineering duty in connection with electrical work, comprising fire control, telephone systems, and wireless installations.

MR. BYRON T. NOTTINGER having completed his work with the Hydroelectric and Gas Company, of Warren, O., as resident engineer, was appointed on January 1, 1910, president and general manager of the Youngstown Armature and Construction Company, Youngstown, O.

MR. S. E. M. HENDERSON, who for the last 10 years has been with the General Electric Company, Schenectady, as switchboard engineer, has resigned and removed to Peterborough, Ont., to take charge of the Canadian General Electric Company's switchboard work.

MR. W. B. CLAYTON, in company with James W. Craig, has opened an office at 161 Summer Street, Boston, Mass., where they will conduct a consulting engineering business, giving special attention to the generation and application of power for industrial establishments.

MR. A. E. SEELIG recently opened at 84 State Street, Boston, Mass., a branch office for the L. J. Wing Manufacturing Company, manufacturers of the typhoon turbine blower for mechanical draft. The company's New England business will be conducted from the Boston office.

MR. ELMER L. JOHNSTON, who since September 1900 has been with the Milwaukee Electric Railway and Light Company, resigned on March 1 as foreman of electrical construction to accept the position of chief electrician and engineer for the Paine Lumber Company, Ltd., Oshkosh, Wis.

MR. EARLE L. OVINGTON has removed from New York City to Newton High-

lands, Mass., where he will continue practice as a consulting electrical engineer. Mr. Ovington is equipping a laboratory to resume his researches with currents of high frequency and high potential.

Mr. Arthur Bessey Smith, of the Automatic Electric Company, Chicago, addressed the electrical students of Purdue University, Lafayette, Ind., on March 22, 1910, on "The Automatic Telephone System." Mr. Smith was formerly assistant professor of telephone engineering at Purdue.

Mr. Robert E. Chetwood, of the American Telephone and Telegraph Company, has been appointed engineer of construction for the Western Union Telegraph Company, with headquarters in New York City. Mr. Chetwood has been in the service of the American Telephone and Telegraph Company since 1895.

Mr. N. R. Stansel resigned in February as engineering inspector in the supervising architect's office, U. S. Treasury Department, Washington, D. C., to accept a position in the power and mining department of the General Electric Company, Schenectady, N. Y. His address is 121 Park Avenue.

Mr. B. A. Hollenbeck was recently transferred from the Hawthorne, Ill. plant of the Western Electric Company, to the New York office, where he is now a district inspector of installation of telephone power equipment. Mr. Hollenbeck was formerly a designing engineer in the power apparatus department.

Mr. William G. Davis, former manager of the New York office of the Westinghouse Storage Battery Company, has temporarily given up personal affairs to administer the estate of his father, E. B. Davis, of Washington, D. C., who died on March 22. Mr Davis's address is 2211 R Street, N. W., Washington, D. C.

Mr. Peter Cooper Hewitt, inventor of the mercury vapor electric lamp which bears his name has won a suit which has been in the Patent Office and the United States courts for six years. The suit involved the question of priority of the invention of a rectifier for transforming alternating to direct current.

Mr. E. D. Tillson, previously electrical engineer for G. M. Gest, subway contractor, New York City, has been engaged by The Safety Insulated Wire and Cable Company, New York City, in the construction department, as engineer in connection with the design and construction of complete underground conduit and cable systems.

Messrs. Frederic H. Keyes and Henry D. Jackson, of Sprague, Keyes and Jackson, consulting engineers, Broad Street, Boston, Mass., recently made an examination of the factories of the S. H. Howe Shoe Company, Marlboro, Mass., and submitted a report bearing on the operating economy of these plants, with suggestions as to improvement.

Mr. Harrison G. Thompson has accepted a position in the sales department of the United States Light and Heating Company, with headquarters at 30 Church Street, New York City. Mr. Thompson was formerly with the railway department of the Westinghouse Storage Battery Company, and was for a long time associated with the Safety Car Heating and Lighting Company.

Mr. Frederick G. Sykes, formerly general manager of the Portland General Electric Company, Portland, Oregon, has become associated with the American Power and Light Company, as president, and with the Electric Bond and Share Company as vice-president,

with headquarters at 71 Broadway, New York City.

MR. JAMES DIXON, formerly sales and production manager of the General Storage Battery Company, and later associated with its successor, the Westinghouse Storage Battery Company, in the sales department, is now a member of the engineering staff of the Crocker-Wheeler Company, with headquarters at Ampere, N. J.

MR. CHARLES L. MICHOD, president of the Southwestern Machinery and Supply Company, manufacturers' agents for Arizona, Nevada and the west coast of Mexico, announces the removal of the company's headquarters from the Union Trust Building to the Central Building, corner Sixth and Main Streets, Los Angeles, Cal.

MR. A. W. TYLER, for the past three years a member of the engineering staff of the United States Gypsum Company, of Chicago, has been transferred to Fort Dodge, Ia., where he will have charge of the construction of a large gypsum plant. When completed this will be the largest plant of its kind in the United States.

MR. LYMAN W. EDDY, who in January left the Western Electric Company to become assistant electrical engineer in the Chicago office of the Crocker-Wheeler Company, has been transferred to the Detroit office as electrical engineer. His business address is 429 Ford Building, and his residence, 39 Owen Avenue, Detroit, Mich.

MR. JACOB A. FOTTLER, formerly assistant professor of electrical engineering and physics, Rhode Island State College, Kingston, R. I., recently resigned and accepted a position with the Boston and Northern and Old Colony Street Railroad companies, in the department of motive power and machinery, as assistant to Mr. Irwin. Mr. Fottler has had several years experience with electric railroads.

MR. J. E. LATTA, former head of the electrical engineering department of the University of North Carolina, has resigned to take a position with the General Electric Company's lamp works at Harrison, N. J. Mr. Latta has devoted much study to illumination and kindred subjects, and in addition to his other work he will assist in the instruction of the special lamp experts being trained in the sales department. Mr. Latta is also giving three half-hour lectures each week during the noon hour to the factory employes on the elements of commerical electrical illuminating engineering.

Annual Meeting of Society for the Promotion of Engineering Education June 23-25, 1910

The Society for the Promotion of Engineering Education will hold its annual meeting at Madison, Wis., on Thursday, Friday and Saturday, June 23, 24 and 25, 1910. The selection of Madison is due to the desire of the Council of the Society to meet the convenience of their members in the middle west. Some of the most important features of the program will be the reports of the committee on entrance requirements and the committee on engineering mathematics, which will be presented for final action. Among the topics which will be discussed at the meeting are, "Technical Education Abroad", "Inspection Trips for Technical Students", and "Efficiency in Technical Education." Full information regarding the meeting and the general work of the Society may be obtained on application to Professor H. H. Norris, Cornell University, Ithaca, N. Y.

Obituary

MR. JAMES J. MAHONY, who for many years was connected with the General Electric Company, in the New York office, died on Saturday afternoon, March 19, 1910. Mr. Mahony was born in Worcester, Mass., on June 16, 1863. For some years he was in the employ of the Thomson-Houston Electric Com-

pany. Later he entered the engineering department of the General Electric Company. From 1888 to 1898 he was chiefly engaged in superintending the installation of electrical equipment in railway stations. All of the West End Street Railway Company's stations, the Metropolitan Elevated Railway stations in Chicago, and all of those of the Brooklyn Heights Railway Company were equipped and completed under Mr. Mahony's supervision. He became an Associate of the Institute on May 17, 1898, and was transferred to the grade of Member on July 25, 1902.

Mr. C. J. Toerring, of C. J. Toerring Company, Philadelphia, Pa., died in that city on April 22, 1910. Mr. Toerring became an Associate of the Institute on April 20, 1894.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

Acetylen in Wissenschaft und Industrie. year 13-date. Halle, a. S., 1910-date. (New exchange).

Almänna Svenska Elektriska, Aktiebolaget Westeras 1883–1908. Göteborg, 1909. (Gift of General Electric Manufacturing Company of Sweden).

American Society of Civil Engineers. Constitution and List of Members Feb. 1910. New York, 1910. (Exchange).

American Street and Interurban Railway Association. Proceedings. 1907–1909. New York, 1907–1909. (Gift of American Street and Interurban Railway Association).

Ballistic electro dynamometer method of measuring hysteresis loss in iron. (University of Kansas Engineering Experiment Station. Bulletin No. 1). By M. E. Rice & Burton McClooum. Lawrence, 1909. (Gift.)

Central Station Development Company. Prospectus 1910. Cleveland, 1910. (Gift of Company.)

Electric Traction for Railway Trains. By E. P. Burch. n.p. n.d. (Gift of University of Minnesota.) Dept. of Electrical Engineering.)

Electricity. By H. M. Hobart. New York, D. Van Nostrand Company, 1909. (Gift of publishers.) Price, $2.00 net.

Contents: Chapter I.—The "Generation" and conduction of electricity. II.—Copper, aluminium, and other conducting materials. III.—Energy. IV.—The Kelvin. V.—Electricity. VI.—Continuous electricity and Ohm's law. VII.—The magnetic field. VIII.—Conductors moving in a magnetic field. IX.—Alternating electricity. X.—Inductance. XI.—The magnetic circuit. XII.—Insulating materials.

Epitome of the work of the Aeronautic Society, New York from July 1908–December, 1909. (Bulletin No. 1). (Gift.)

Fifth Avenue Building site of 5th Ave. Hotel, Madison Square, New York. New York, n. d. (Gift of The Fifth Avenue Building Company.)

Die Frequenzmesser und Dampfungsmesser der Strahlentelegraphie. By Euguen Nesper. Leipzig, 1907. (Gift of Richard Pfund.)

Insurance Society of New York. Bulletin Vol. I, No. 7. New York, 1910. (Gift of Society.)

International American Scientific Congress to be held in Buenos Aires from the 10th to the 25th of July 1910. Bulletin No. 1. n.p. n.d. (Gift.)

National Irrigation Congress. Official proceedings of 17th Congress. Spokane, 1909. (Gift of Mr. Huntington.)

New York (State) Public Service Commission—First District. Proceedings. Vols. 1–3, July 1, 1907–Dec. 31, 1908. n.p. n.d. (Gift of Public Service Commission.)

——Report of grade crossings in New York City and the need of change in the grade crossing law. Appendix B to Annual report for 1909. Albany, 1910. (Gift.)

Notes on alternating current phenomena. By G. D. Shepardson. Minneapolis, 1906. (Gift of Uni-

versity of Minnesota Dept. of Electrical Engineering.)

Society of Chemical Industry. List of Members, 1910. London, 1910. (Exchange.)

Standardization of high potential electric currents. By E. C. Titus. n.p. n.d. (Gift of The Baker Electric Company.)

Static brush discharge. By F. De Kraft. (Reprint from Journal of Advanced Therapeutics, Aug. 1909). n.p. n.d. (Gift of The Baker Electric Company.)

Thermal conductivity of fire-clay at high temperatures. (University of Illinois. Engineering Experiment Station. Bulletin No. 36.) By J. K. Clement & W. L. Egy. Urbana, 1909. (Gift.)

U. S. Bureau of Standards. Circular No. 21. Washington, 1910. (Exchange.)

U. S. Circuit Court. Indicating safety fuse case. Opinion of Judge Ray, Feb. 14, 1910. New York, n.d. (Gift.)

——Metal sleeve drum controller case, Lange & Lamme patent No. 518,693 Order for preliminary injunction, Feb. 25, 1910.

U. S. Patent Office. Report of the Commissioner. 1849, Vol. 2; 1850, Vols. 1–2; 1852, Vol. 1; 1855, Vols. 2–3; 1860, Vol. 2; 1861, Vol. 2; 1862, Vol. 1; 1867, Vol. 2. Washington, 1850. 1851, 1853, 1856, 1861, 1863, 1864, 1868. (Purchase.)

University of Minnesota. Bulletin of the College of Engineering and the Mechanic Arts 1909–10. Minneapolis, 1909. (Gift.)

Washington University. Bulletin Feb. 1910. St. Louis, 1910. (Gift.)

Trade Catalogues

Emerson Electric Mfg. Co., St. Louis, Mo. Catalogue No. 5400, Alternating current fans. 71 pp.

Fort Wayne Electric Works, Fort Wayne Ind. Bulletin No. 1118—Type " A " transformers. 11 pp.

——Bulletin No. 1119—" Northern " type " B " direct current motors. 3 pp.

——Description of the " Paul " double-acting piston pump. 16 pp.

UNITED ENGINEERING SOCIETY

Designing and detailing of simple steel structures. By C. T. Morris. Columbus, 1909. (Gift of Engineering News Publishing Company) Price, $2.25 net.

CONTENTS. Chapter I.—Riveting. II.—Designing and Estimating. III.—Manufacture and erection. IV.—Roofs. V.—Plate girder bridges. VI.—Pin-Connected Bridges. VII.—Details of pin-connected bridges.

International Who's Who 1910–11. New York, International Who's Who Publishing Co., 1910. (Purchase.)

GIFT OF SCHNEIDER & COMPANY, PARIS.

Acier au Manganese, proprietes et applications. (Extrait du Journal le Genie Civil.) Paris, 1909.

Acier au Manganese. 1908.

Acier speciaux pour pieces d'Automobiles. Objects exposes Paris, 1906.

Album des Fers et Aciers. 1895.

Etablissements de MM. Schneider & Cie. Nevers, 1900.

Materiel automobile. 1909.

Materiel electrique a courants alternatifs. Alternateurs. 1909.

——Dynamos Schneider Type " E " 1909, type " S " 1909.

——Moteurs triphases. 1905.

——Transformateurs. 1907.

Principales installations comportant des dynamos " Schneider " a courant continu. Liste de references. 1905

——Annexe No. 1. 1906–07.

Principales installations comportant du materiel electrique a courants alternatifs de notre dernier type. Liste des references. 1906.

——Annexe No. 1. 1907.

Travaux d'amelioration du port du Havre. Paris, 1907.

Compagnie des Forges et Acieries de la Marine et d'Honiécourt. France. Iron and steel parts for automobiles for buildings, wheels, castings of all kinds, projectiles, guns, fire arms. 75 pp.

OFFICERS AND BOARD OF DIRECTORS, 1909-1910.

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(Term expires July 31, 1910.)
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(Term expires July 31, 1910.)

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NOTE:—The Institute Constitution provides that the above named twenty-three officers shall constitute the Board of Directors.

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Boston.............Feb. 13, '03	D. C. Jackson.	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago....................1893	J. G. Wray.	E. N. Lake, 181 La Salle St., Chicago. Ill.
Cleveland..........Sept. 27, '07	H. L. Wallau.	F. M. Hibben, 807 The Cuyahoga Bldg., Cleveland, O.
Fort Wayne........Aug. 14, '08	E. A. Wagner.	J. V. Hunter, Fort Wayne Electric Works. Ft. Wayne, Ind.
Ithaca.............Oct. 15, '02	E. L. Nichols.	B. C. Dennison, Cornell University Ithaca, N. Y.
Los Angeles........May 19, '08	J. A. Lighthipe.	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Madison...........Jan. 8, '09	M. H. Collbohm	H B. Sanford, Univ. of Wisconsin, Madison, Wis.
Mexico............Dec. 13, '07	E. Leonarz.	W. A. Ferguson, Mex. Lt. & Pr. Co., Mexico, Mex.
Milwaukee.........Feb. 11, '10	W. H. Powell.	L. L. Tatum, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota..........Apr. 7, '02	J. C. Vincent.	J. H. Schumacher, 2716 University Ave., Minneapolis, Minn.
Norfolk............Mar. 13, '08		R. R. Grant, P. O. Box 254, Norfolk, Va.
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Portland, Ore......May 18, '09	O. B. Coldwell.	L. B. Cramer, 720 Corbett Building, Portland, Ore.
San Francisco.....Dec. 23, '04	George R. Murphy	S. J. Lisberger, 445 Sutter St., San Francisco, Cal.
Schenectady.......Jan. 26, '03	M. O. Troy	R. H. Carlton, Gen. Elec. Co., Schenectady, N. Y.
Seattle.............Jan. 19, '04	A. A. Miller.	W. S. Hoskins, 1428 21st Avenue, Seattle, Wash.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	George W. Lamke, Washington University, St. Louis, Mo
Toledo.............June 3, '07	M. W. Hansen.	Geo. E. Kirk, 1649 The Nicholas, Toledo, O.
Toronto...........Sept. 30, '03	H. W. Price.	W. H. Eisenbeis, 1207 Traders' Bank Bldg., Toronto, Can.
Urbana............Nov. 25, '02	Charles T. Knipp.	J. M. Bryant, 610 West Oregon St., Urbana, Ill.
Washington, D. C...Apr. 9, '03	Philander Betts	M. G. Lloyd, Bureau of Standards, Washington D. C.

Total, 25

LIST OF BRANCHES.

Name and when Organized.	Chairman.	Secretary.
Agricultural and Mechanical College of Texas............Nov. 12, '09	V. H. Braunig.	R. T. Shiels, A. and M. Col. of Tex., College Sta., Texas
Arkansas, Univ. of..Mar. 25, '04	W. B. Stelzner.	F. S. White, 523 Willow St., Fayetteville, Ark.
Armour Institute...Feb. 26, '04	Edward Sherwin.	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Case School, Cleveland.............Jan. 8, '09	C. N. Weems.	S. G. Hibben, 2171 Cornell St., Cleveland, O.
Cincinnati, Univ. of..Apr. 10, '08	C. R. Wylie.	Ralph B. Kersay, 315 Jackson St., Carthage, Ohio.
Colorado State Agricultural College......Feb. 11, '10	E. J. Falloon.	D. E. Byerley, 229 N. Loomis Street, Fort Collins, Colo.
Colorado, Univ. of...Dec. 16, '04	E. A. Robertson.	A. P. Sunnergren, 1209 Penn., Boulder, Colo.
Iowa State College...Apr. 15, '03	Frank K. Shuff.	M. W. Pullen, Iowa State College, Ames, Ia.
Iowa, Univ. of.......May 18, '09	H. E. Scheark.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col. Jan. 10, '08	R. E. Talley.	B. F. Eyer, 513 Fremont St., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	V. S. Foster.	R. L. Ponsler, Univ. of Kansas, Lawrence, Kans.
Lehigh University....Oct. 15, '02	W. W. Broadbent.	Howard M. Fry. Lehigh University, Bethlehem, Pa.
Lewis Institute.......Nov. 8, '07	Frank Burch.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Maine, Univ. of......Dec. 26, '06	A. T. Childs.	J. P. King, University of Maine, Orono, Maine.
Michigan, Univ. of...Mar. 25, '04	E. B. McKinney.	Gerald J. Wagner, 454 S. First St., Ann Arbor, Mich.
Missouri, Univ. of....Jan. 10, '03	H. B. Shaw.	A. E. Flowers, Univ. of Missouri, Columbia, Mo.
Montana State Col...May 21, '07	C. C. Kennedy.	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of...Apr. 10, '08	Geo. H. Morse.	V. L. Hollister, Station A, Lincoln, Nebraska.
New Hampshire Col..Feb. 19, '09	A. M. Buck.	T. A. Thorp, New Hampshire College, Durham, N. H
North Carolina Col. of Agr. and Mech. Arts....Feb. 11 '10	Wm. H. Browne, Jr.	E. B. Moore, N.C.C.A. and M.A., West Raleigh, N.C.
Ohio State Univ......Dec. 20, '02	H. W. Leinbach.	F. L. Snyder, 128 E. Blake Ave., Columbus, Ohio.
Oregon State Agr. Col. Mar. 24, '08	E. R. Shepard.	W. Weniger, Ore. State Agricul. College, Corvallis, Ore.
Penn. State College...Dec. 20, '02	H. H. Agee.	H. E. Smith, Penn. State College, State College, Pa.
Purdue Univ.........Jan. 26, '03	C. F. Harding.	H. T. Plumb, Purdue University, Lafayette, Ind.
Rensselaer Polytechnic Institute.......Nov. 12, '09	E. D. N. Schulte	W. J. Williams, Rensselaer Poly. Institute, Troy, N Y.
Stanford Univ.......Dec. 13, '07	C. L. Bradley.	C. P. Taylor, Stanford University, California
Syracuse Univ.......Feb. 24, '05	W. P. Graham.	R. A. Porter. Syracuse University, Syracuse, N. Y.
Texas, Univ. of......Feb. 14, '08	B. E. Kenyon.	J. A. Correll, University of Texas, Austin, Tex.
Wash., State Col. of..Dec. 13, '07		M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ....Feb. 26, '04	H. F. Thomson.	George W. Pieksen, Washington University, St. Louis, Mo.
Worcester Poly. Inst..Mar. 25, '04	Ray H. Taber.	C. E. Putnam, Worcester Poly. Inst., Worcester Mass.

Total, 30.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

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Vol. XXIX **June, 1910** No. 6

Annual Convention White Mountains

JUNE 27–30, 1910.

The twenty-seventh Annual Convention of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS will be held at The Waumbek, Jefferson (White Mountains) N. H., June 27, 28, 29 and 30, 1910.

Institute Headquarters.

The Institute headquarters during the convention will be at the Waumbek. On arriving each member should register at Institute headquarters and obtain identification badge. The convention sessions will be held in the hotel.

PROGRAM

(Subject to change)

Monday, June 27

AFTERNOON SESSION—2 P.M.

1. *President's Address*, Lewis B. Stillwell.
2. *Headlight Test*. By C. Francis Harding and A. N. Topping.
3. *Light Standards*. By Edward B. Rosa.
4. *Modern Oil Switch*. By A. R. Cheyney.

Tuesday, June 28

MORNING SESSION—10 A.M.

5. *Disruptive Strength with Transient Voltages*. By Charles P. Steinmetz and J. L. R. Hayden.
6. *The Electric Strength of Air*. By John B. Whitehead.
7. *Vector Power in Alternating-Current Circuits*. By Arthur E. Kennelly.
8. *Determination of Transformer Regulation Under Load Conditions and Some Resulting Investigations*. By Adolph Shane.

EVENING SESSION—8 P.M.

9. *American Telegraph Engineering. Notes in History and Practice*. By Wm. Maver and Donald McNicol.
10. *Telephone Engineering Around the Golden Gate*. By Arthur B. Smith.
11. *Interaction of Fly-Wheels and Motors When driving Roll Trains by Induction Motors*. By F. G. Gasche.
12. *Recent Progress in Exact Electrical Measurements*. By Clayton H. Sharp and W. W. Crawford.

Wednesday, June 29

No sessions; trip to Mount Washington.

Wednesday evening at 6 o'clock there will be a dinner and discussion by the Sections Committee and Section delegates.

Thursday, June 30

MORNING SESSION—10 A.M.

13. *Electric Locomotive Design*. By N. W. Storer and Eaton.
14. *A Method of Determining the Adequacy of an Electric Railway System*. By R. W. Harris.
15. *Third Rail Construction*. By Jesse H. Davis.
16. *Power Economy in Electric Railway Operation—Coasting Clock Tests on the Manhattan Elevated Railway*. By H. S. Putnam.

Thursday evening there will be a dinner followed by a discussion under

the auspices of the Educational Committee.

NOTE: Papers Nos. 4, 5, 10 and 11 are printed in May and June PROCEEDINGS. Members who desire to discuss any other of the convention papers may obtain advance copies as soon as they are available, upon application to the Institute, 33 West 39th Street, New York.

Convention Committee 1910

PAUL SPENCER, Chairman, Philadelphia, Pa.
PHILIP P. BARTON, Niagara Falls, N. Y.
A. W. BERRESFORD, Milwaukee, Wis.
H. E. CLIFFORD, Cambridge, Mass.
LOUIS A. FERGUSON, Chicago, Illinois.
J. H. FINNEY, Washington, D. C.
A. S. LANGSDORF, St. Louis, Mo.
PAUL M. LINCOLN, Pittsburgh, Pa.
FARLEY OSGOOD, Newark, N. J.
A. M. SCHOEN, Atlanta, Ga.
SEVERN D. SPRONG, New York City.
CHARLES W. STONE, Schenectady, N. Y.
H. W. TOBEY, Pittsfield, Mass.
J. B. WHITEHEAD, Baltimore, Md.
J. G. WRAY, Chicago, Ill.

Entertainment

The Convention Committee announces the following events:

Monday evening, June 27, there will be a reception and dance at the Waumbek.

Tuesday afternoon, June 28, there will be golf and tennis tournaments.

Wednesday, June 29, is reserved to make the trip to Mount Washington, which will require practically the whole day. The trip may be made by rail, starting from the hotel at 7:45 a.m. and returning about 4:30 p.m. Excursion tickets will be about $5.00 per person.

Thursday afternoon, June 30, there will be a ball game, and the golf and tennis tournaments will be concluded. In the evening there will be a " putting " contest by electric light.

The committee has arranged for suitable prizes for the various golf and tennis tournaments.

There is an excellent 18-hole golf course on the hotel grounds, a baseball ground on the course and a putting green near the hotel. Three tennis courts are also available. Automobiles and saddle horses may be hired at the hotel. Many points of interest are readily accessible from the hotel by rail and automobile.

Transportation

Special summer excursion and circular tour rates to White Mountain points will be available for members and guests attending the convention. These rates will be in force the latter part of June on practically all transportation lines. Tickets should be purchased to Jefferson, New Hampshire.

Members should consult their local ticket agents regarding routes and rates, preferably several days before they intend to start for the convention.

Hotel Rates

Each member should arrange for his own hotel accommodations. Early application is desirable. Correspondence on this subject should be addressed to Charles V. Murphy, manager, " The Waumbek," Jefferson, New Hampshire. The hotel management has made the following rates, on the American plan, for members and guests who attend the convention. Single rooms $4 per day per person, with bath, $5 to $6; double rooms, for two persons, $7.50 per day, with bath $9; two single rooms, bath connecting, for two persons, $10 to $11 per day; one double and one single room communicating with bath, for three people, $13 to $15 per day.

Pacific Coast Convention, San Francisco May 5, 6 and 7, 1910

The Pacific Coast Convention, organized by the High-Tension Transmission Committee, was the first regular Institute meeting held west of the Rocky Mountains, and marks another advance step in carrying out a policy which will emphasize the national character of the American Institute of Electrical Engineers. The registered attendance

was 150 of which 19 were from distant points, there being seven from the Atlantic States. The local attendance was 131, mostly Members and Associates but including many engineers of other branches.

The opening session on Thursday morning was called to order by President Stillwell, after which Secretary Pope made a number of announcements. Professor Harris J. Ryan, of Stanford University, local member of the High-Tension Transmission Committee, delivered the address of welcome to which President Stillwell responded, tracing the growth of the Institute since its inception and laying stress upon the number of special problems that have recently presented themselves, among them being that of technical committees and the holding of Institute meetings in different parts of the country for the convenience of members in such sections.

Mr. George I. Rhodes, assistant engineer of the Interborough Rapid Transit Company, New York, presented in abstract his paper on "Parallel Operation of Three-Phase Generators with their Neutrals Interconnected." (May 1910 PROCEEDINGS). The discussion included remarks on the advantages and disadvantages of grounding the neutral. In the afternoon, Mr. Paul M. Downing presented his paper on "The Developed High-Tension Net Work of a General Power System." (April 1910 PROCEEDINGS).

Friday morning, Mr. John J. Frank's paper on "Observation of Harmonics in Current and Voltage Wave Shapes of Transformers," (May PROCEEDINGS) was presented in abstract by Mr. G. Faccioli of Pittsfield, and an interesting discussion followed. At the afternoon session Mr. A. H. Babcock read his paper on "Transmission Line Crossings of Railroads Rights of Way." (Page 885 of this issue). Following Mr. Babcock's paper, Mr. John C. Hays presented a paper on "Hydroelectric Development and Irrigation," being based on the operation of the Mount Whitney Power Company's system in Southern California (April 1910 PROCEEDINGS).

At the session on Saturday morning Mr. A. M. Hunt presented his paper on "Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants under Pacific Coast Conditions." (April PROCEEDINGS). It was voted that a cablegram expressing the sympathy of the membership in the death of King Edward be sent to the British Institution of Electrical Engineers.

The message was read at the meeting and sent by telegraph from San Francisco in the evening.

The following resolutions were adopted, after which the Convention adjourned.

Whereas, the high character of the papers presented at this meeting of the Institute held under the auspices of the High-Tension Transmission Committee, the large attendance at the various sessions, and the interesting and profitable discussion of the papers, not only indicate but show conclusively, that this meeting has been of great advantage to the Institute, will serve to stimulate the interest of the membership generally, and to strengthen the bond of union existing between our members residing in the different parts of this great and partially developed country.

Resolved, that the Secretary of the Institute be and hereby is instructed to extend our most hearty thanks for the royal reception, broad hospitality and many courtesies extended to the members and guests by the citizens and organizations on the Pacific Coast and that he transmit a copy of these resolutions to Professor Harris J. Ryan, Mr Ralph D. Mershon, Mr. H. S. Putnam, The Home Telephone Company, Pacific Gas and Electric Company, The Great Western Power Company, The Northern Electric Railway Company, The Southern Pacific Railway Company and Stanford University.

Resolved, that our most hearty congratulations be extended to the chairmen and members of the High-Tension Transmission Committee of the Institute, the Meetings and Papers Committee and to the Local Committee of Arrangements for the successful culmination of their well planned efforts to promote the welfare of the Institute and to increase its efficiency.

WALTER F. WELLS
Brooklyn, N. Y.
MARKHAM CHEEVER
Salt Lake City, Utah
JOHN HARISBERGER
Seattle, Wash
Committee on Resolutions

San Francisco, Cal.
May 7, 1910

The visiting ladies were entertained at various teas, theatre parties and sight-seeing trips. Thursday evening the visiting members were entertained by the local Executive Committee at a dinner at the Bohemian Club. Friday evening there was a subscription banquet at the Poodle Dog, attended by about 70 members, with Mr. S. G. McMeen as toastmaster. Saturday afternoon a large number visited Stanford University at the invitation of Professor Harris J. Ryan, who gave a lecture and experimental demonstration of his cathode ray power indicator.

Many local power plants were visited, and on Sunday night a party of visiting members started on a trip of inspection over the lines of the Pacific Gas and Electric Company, the Great Western Power Company and the Northern Electric Railway Company

Annual Meeting New York, May 17, 1910

The 27th Annual Meeting of the Institute was held in the Auditorium of the Engineers' Building, 33 West 39th Street, on Tuesday, May 17, 1910. Mr. Calvert Townley, in the absence of President Stillwell, called the meeting to order at 8:15 o'clock promptly, and announced that the President had requested him to preside at the meeting, by reason of his absence on the Pacific coast in connection with the recent Institute meeting in San Francisco. After the appointment of a proxy committee, consisting of Messrs. H. W. Buck H. H. Barnes, Jr., and W. G. Carlton, the Chairman called for the presentation of the Directors Annual Report, which was read in abstract by the Secretary. [Report in full at end of Section II.]

The Chairman: Unless some one calls for it, the Secretary will not read the entire report, as it has been printed and I presume you all have copies of it, but if any member wishes to make inquiry regarding any feature in the report the Secretary will be glad to respond.

Election of Officers

In the absence of George A. Baker, Chairman of the Committee of Tellers, the Secretary read the duplicate copy of the report of the Committee of Tellers and announced that the total number of ballot envelopes received was 2342: rejected on account of envelopes bearing no identifying names 37, rejected on account of voters being in arrears for dues 84, rejected on account of ballot not being enclosed in inner envelope 50, rejected on account of having reached the Secretary's office after May 1, 49, leaving 2122 valid ballots.

The report of the Committee of Tellers showed the following result: For President, Dugald C. Jackson, 2100; for Vice-President, P. H. Thomas, 2080; H. W. Buck, 2090; Morgan Brooks 1955. For Managers, H. H. Barnes, Jr., 2064; C. E. Scribner, 2074; W. S. Rugg, 2043; R. G. Black, 1881. For Treasurer, George A. Hamilton, 2115; for Secretary, Ralph W. Pope, 2002, there being other scattering ballots for each of these offices.

The Chairman: Gentlemen, you have heard the Secretary's announcement. It therefore becomes my pleasant duty to declare elected for the coming year Mr. Dugald C. Jackson as President, Messrs. P. H. Thomas, H. W. Buck and Morgan Brooks as Vice-Presidents, for Managers, Messrs. H. H. Barnes, Jr., C. E. Scribner, W. S. Rugg and R. G. Black; for Treasurer, Mr. George A. Hamilton; for Secretary Mr. Ralph W. Pope.

Constitutional Amendments Lost

The Secretary read the report of the Committee of Tellers showing that the total number of ballots received for the voting on the Constitutional Amendments was 2129, of which 28 were rejected on account of bearing no identifying name on their envelopes, 62 rejected on account of voter being in arrears for dues, and five rejected because they were duplicate ballots, leaving 2034 valid ballots. Of these,

were in favor of the adoption of the proposed Amendment, 1453; against the adoption of the proposed amendment, 560; blank 21.

The Chairman: The Constitutional provision for amendment requires that there must be ballots cast equal at least to 30 per cent of the number of members and associates, and in order that the amendment shall be adopted, at least 75 per cent of those voting must vote in the affirmative. The membership in the Institute at the end of the fiscal year was 6681, so that the requisite number of ballots cast exceeds the 30 per cent required, 2005, but the Amendment fails because there are 560 votes in the negative and 1453 votes in the affirmative. The required percentage did not vote in favor of the amendment, and it is therefore lost.

Presentation of Edison Medal

The Chairman: We have another pleasant duty to perform to-night. The first medal that has ever been awarded under the Deed of Gift creating the Edison medal is to be presented. This medal is to be awarded annually to that person whom the Edison Medal Committee may consider to have been most deserving for meritorious achievement in electrical science, or electrical engineering or the electrical arts, and the evening of the annual meeting of the Institute is the date set in the by-laws of the Edison Medal Committee when this medal must be presented. The medal was awarded on December 16, last, to Dr. Elihu Thomson, and the certificate of award duly presented to him on the occasion of the annual dinner of the Institute. Unfortunately for us, Dr. Thomson is detained by illness, which we hope and understand is not of a serious nature, but this will prevent him from being with us this evening, and we will therefore make these proceedings strictly informal and are not able to actually hand the medal to Dr. Thomson. I have here this very beautiful medal in gold [exhibiting medal] which has been prepared from a special design which received great study and care, and I am going to ask Mr. Charles W. Stone to act for Dr. Thomson in receiving this medal from the Chair, so that the provisions of the by-laws may be strictly carried out, and you will be witnesses to that fact. [The Chairman handed the medal to Mr. Stone.]

Mr. Stone accepted the Medal in behalf of Dr. Thomson.

The Secretary then read the report of the Proxy Committee, and announced the results thereof, whereupon the Chairman announced that there being at least 350 persons represented by proxy, a quorum was present.

A paper entitled " Some Developments in Modern Lighting Systems," was then presented by Charles W. Stone.

After the discussion, a paper was presented by John W. Howell on " Metal Filament Lamps." Both of these papers are printed in Section II of this issue, Dr. W. D. Coolidge of the Research Laboratory of the General Electric Company followed with a paper on " Ductile Tungsten," which is also printed in Section II.

Before proceeding with the discussion Chairman Townley announced that there were present as guests of the U. S. National Committee of the International Electrotechnical Commission, Dr. W. Jaeger of Berlin, Mr. F. E. Smith of London and Professor Paul Janet of Paris who had been delegated to represent their respective countries in making certain scientific investigations at the Bureau of Standards in Washington. Dr. E. B. Rosa then addressed the meeting upon the historical connection between the meeting of the Chamber of Delegates at St. Louis in 1904, the Electrical Conference at London in 1908, and the work which is now being done at the Bureau of Standards, in Washington.

A complimentary dinner was given to the foreign representatives at Hotel Astor prior to the meeting, by the United States Committee of the International Electrotechnical Commission.

Directors' Meeting, May 17, 1910

The regular monthly meeting of the Institute Board of Directors was held at 33 West 39th Street, New York City, on Tuesday May 17, 1910. The Directors present were: Past-President Henry G. Stott, New York; Vice-presidents, Cummings C. Chesney, Pittsfield, Mass.; Calvert Townley, New Haven, Conn.; Paul M. Lincoln, Pittsburgh, Pa.; Paul Spencer, Philadelphia, Pa.; Managers, David B. Rushmore, Schenectady, N. Y.; W. G. Carlton, New York; Charles W. Stone, Schenectady, N. Y.; A. W. Berresford, Milwaukee, Wis.; William S. Murray, New Haven, Conn.; Percy H. Thomas New York, Severn D. Sprong, New York; Treasurer, George A. Hamilton; Elizabeth, N. J.; Secretary, Ralph W. Pope.

Seventy-nine candidates for admission to membership in the Institute as Associates were elected.

Sixty-three Students were declared enrolled.

Seven Associates were transferred to the grade of Member, as follows:

W. F. Stuart-Menteth, Electrical Engineer, Public Works Department, Bombay Government, Bombay, India.

Charles H. Merz, Consulting Engineer, 28 Victoria Street, Westminster, London, England.

Max P. Collbohm, Electrical Engineer, Madison, Wis.

Thomas West Gardner, Chief Electrical Engineer, Cumberland Telephone and Telegraph Company, Nashville, Tenn.

Simon B. Storer, Consulting Electrical Engineer, Syracuse, N. Y.

Warren H. Fiske, Electrical Engineer, Mexican Light and Power Company, Mexico City, Mex.

Charles T. Mosman, Electrical Engineer, General Electric Company, Boston, Mass.

Associates Elected May 17, 1910

Anderson, Samuel Horace, Electrical Engineer, Pacific Electrical Railway Co.; res., 935 Dunn Avenue, Los Angeles, Cal.

Andrews, Edmund L., Plant Department, American Telephone & Telegraph Co., 15 Dey Street, New York City.

Appleton, Albert Thomas, Electrical Superintendent, Port Colborne Mill, Canada Cement Co., Ltd. Port Colborne, Ont.

Archer, Elmer T., Partner, Archer, Rollins & Co., 535 Beals Building, Kansas City, Missouri.

Baker, Guy, Laboratory Assistant, General Electric Co.; res., 204 Union St., Schenectady, N. Y.

Bixby, Horace Emery, Electrician and Draughtsman, Atchison, Topeka & Santa Fe Railroad, Topeka, Kansas.

Broughall, Henry Thomas, Electrical Engineer, 829 Princess Avenue; res., 115 Eleventh St., Brandon, Manitoba.

Burnett, Robert Spear, Electrical Tester, Safety Car Heating & Lighting Co., 206 Erie Avenue, Jersey City.

Cameron, John Bobbs, Engineer, George W. Jackson, Inc., 754 Jackson Blvd.; res., 3706 Grand Blvd., Chicago, Ill.

Carey, William Gibson, General Electric Company; res., 17 Gillespie St., Schenectady, N. Y.

Chaffee, William N., Engineer, Westinghouse Electric & Mfg. Co.; res., 123 N. Negley Ave., Pittsburg, Pa.

Copley, Everett, Sales Engineer, Westinghouse Electric & Mfg. Co., 165 Broadway; res., 423 W. 118th St., New York City.

Deesz, Louis Aspell, Station Operator, Colorado Light & Power Company, Cripple Creek, Colorado.

de Lapotterie, Harry, Superintendent Motive Power, Arthur Koppel Co. Koppel, Pa.

Drummond, William, Manager, Drummond Electrical Company, 301 Richards Block, Lincoln, Neb.

ESPENCHIED, LLOYD, Engineer, Telefunken Wireless Telegraph Co. of United States, 111 Broadway, New York City.

HAGOOD, LEE, Lighting Department, General Electric Co.; res., The Alexandria, Schenectady, N. Y.

HAYES, GEORGE, Westinghouse Electric & Mfg. Co., 131 State St.; res., Heminway Chambers, Boston, Mass.

HEINE, JOHN FARNSWORTH, Assistant Examiner, U. S. Patent Office; res., 610 21st St., N. W., Washington, D. C.

HEYL, RUSSELL GEORGE, Erecting Engineer, Westinghouse Electric & Mfg. Co., 121 East Baltimore St., Baltimore, Md.

HOUSEWORTH, WALTER SCOTT, JR., Pacific Light & Power Company, Los Angeles; res., 381 Summit Ave., Pasadena, Cal.

HUNT, RAYMOND, Superintendent Electrical Department, Tidewater Power Co., Wilmington, N. C.

IRVINE, THOMAS FRANCIS, Electrical Engineer, Central District & Printing Telegraph Co., 1326 Fulton Bldg., Pittsburg, Pa.

KLEMM, CARL ANDREW, Salesman, Westinghouse Electric & Mfg. Co., Cincinnati, Ohio; res., 2213 Slaughter Ave., Louisville, Ky.

KNIGHT, ROBERT, General Electric Co., 84 State St., Boston; res., 11 Howe St., Dorchester, Mass.

LEFFINGWELL, WILLIAM HOWLAND, Chief Engineer, Mono Power Co., Bishop, Cal.

MACDONALD, ROBERT ROSS, Electrical Engineer, Smith, Kerry & Chace, 300 Jarvis St., Toronto, Ont.

MANHART, GEORGE HARLAND, Foreman Electrical Construction, Pumping Stations, U. S. Reclamation Service, Minidoka, Idaho.

MARTELL, HARRY CLARKE, Engineer and Wireman, The Isthmian Canal Commission, Balboa, Canal Zone.

MASON, FRANK HENRY, Engineer, Central Maine Power Co., Waterville, Maine.

MAY, EDMUND S. C., Telephone Engineering, Plant Dept., American Telephone & Telegraph Co., 22 Thames St., New York City.

MCBRIAN, EDWARD WILFRED, Consulting Engineer, 301 Grand Building, Macon, Georgia.

MCCABE, JAMES, Superintendent, Greenville-Caroline Power Co., Greenville, S. C.

MCKEEHAN, DONALD CHANDLER, Electrician, Tomboy Gold Mines Co., Ltd., Smuggler, Colorado.

MCNUTT, ROBERT HUGH, Testing Department, General Electric Co.; res., 525 Liberty Street, Schenectady.

MIFFLIN, WILLIAM PHILLIPS, Superintendent, Snake Creek Power Plant, Midway, Utah.

MORGAN, WILLIAM BASSETT, Chief Engineer, Northern Light, Power and Coal Co., Dawson, Yukon.

MULHOLLAND, BRENDAN FRANCIS PATRICK, Inspector, Hydro-Electric Power Commission, Toronto, Canada.

MULLEN, WALTER GREGORY, 1701 10th Street, Baltimore, Maryland.

NEWELL, FRANK CLARENCE, JR., Editor, National Text-Book Co., 45 West 34th Street, New York City.

NOBLE, EDWARD ELTING, Superintendent of Construction Department, The Cleveland Electric Illuminating Co., Cleveland, O.

O'CONNELL, JAMES HORATIO, Assistant, to William Stone, Victorian Railways, Victoria, Australia.

OLMSTEAD, FREDERIC WALDEMAR, 569 Madison Street, Brooklyn, N. Y.

PEEBLES, FRANK W. L., Consulting Engineer, Chemical Building; res., 3666 Laclede Ave., St. Louis, Mo.

PETERSEN, EJLERT, Electrical Engineer, Union Oil Co., Mills Bldg.; res., 105 Steiner St., San Francisco, Cal.

PIERCE, GUY CARLETON, 165 Broadway, New York City.

RAPELJE, HERBERT DE WITT, Consulting Engineer, 511 Southern Building, Wilmington, North Carolina.

ROBB, ALEXANDER DUFFIELD, Assistant Superintendent, Canadian Niagara Power Co., Niagara Falls, Ont.

RYAN, LEWIS STODDARD, Artillery Engineer, Coast Artillery Corps, United States Army, Fort DuPont, Delaware.

SALT, ALBERT L., General Purchasing Agent, Western Electric Company, 463 West Street, New York City.

SALTZ, LAWRENCE WILLIAM, Electrical Engineer, with C. C. Bateson, Cleveland, Ohio.

SANDS, HOWARD TUXBURY, General Manager, Malden Electric Company, 137 Pleasant Street, Malden, Mass.

SCHOLZ, WILLIAM PAUL, JR., Inspector, Interborough Rapid Transit Co., 165 Broadway, New York City.

SCOTT, EDGAR GEORGE, Assistant, Thomas & Neall, 12 Pearl Street, Boston, Mass.

SETZLER, HENRY, Superintendent of Construction, W. H. Jackson Co., 485 Old Colony Bldg., Chicago, Ill.

SKOGLAND, DAVID, Operator, Fisk Street Station, Commonwealth Edison Company; res., 225 Oak Street, Chicago.

SLOAN, JOHN SCHAFFER, Westinghouse, Church, Kerr & Co., Pittsburg; res., 1106 Center Street, Wilkinsburg, Pa.

SPROUL, EDGAR, General Foreman Overhead City Electric Co., 347 Grant Avenue, San Francisco, California.

STAEGE, STEPHEN A., Sales Engineer, Allis-Chalmers Co., Syracuse, N. Y.

STARR, HOWARD WHITE, Vice President, Schenectady Power Company; res. 11 Front Street, Schenectady, N. Y.

STEELE, GEORGE FREDERICK, Manager Lighting & Power Department, General Electric Co., Boston, Mass.

STEINFORT, CARL EDWARD, Superintendent of Construction, Chippewa Valley Railway, Light & Power Co., Eau Claire, Wis.

STEVENS, HENRY WARREN, Assistant Superintendent, Street Installation Dept., Edison Electric Illuminating Co., Boston, Mass.

TARNBERT, EDMUND EMIL, General Foreman, Electrical Manufacturing Co., 459 East Third St., Los Angeles.

THUNEN, EDWARD GEORGE, Electrical Engineer, Yuba Consolidated Gold Fields, Hammonton, Cal.

TOWNSEND, ARTHUR JEAN, Electrical Engineer, Canadian Sheet Steel Corporation, Morrisburg, Ont.

TROUT, SHELLEY B., Station Operator, Seattle-Tacoma Power Co., Tacoma, Wash.

VATTER, WILBUR LEWIS, Engineering Department, American Telephone & Telegraph Co., 15 Dey St., New York.

VIRTUE, MATHEW LEONARD, Engineer, Vancouver Power Co., Lake Buntzen, B. C.

VON WELLER, LAURENCE JUSTIN, City Electrician, City of Albany, Georgia.

WALLING, BURNS TRACY, Captain, United States Navy, Navy Yard, New York.

WARDWELL, WILLIAM EMORY, Salesman, Electrical Department, American Steel & Wire Co., Worcester, Mass.

WEST, JOHN, Assistant to Power Expert, Empire District Electric Co., Joplin, Missouri.

WHEATON, H. ASHLEY, Superintendent of Power Plant, Compania de Gas y Electricidad de Habana, Habana, Cuba.

WHISTON, WILLIAM CORTELYOU, Assistant Electrical Engineer, Public Service Commission, 154 Nassau St., New York City.

WIDENMANN, WILLIAM ADOLPH, Draughtsman, Sierra and San Francisco Power Co., Berkeley, Cal.

WILKINS, ARTEMAS ORLANDO, Electrician, Estey Organ Company, Brattleboro, Vt.

WILLIAMSON, GEORGE EMERY, Engineer of Works, The Union Metallic Cartridge Co., Bridgeport, Conn.

WOOD, WILLIAM MAXWELL, Electrical Engineer, W. S. Barstow & Co., Electric Building, Portland, Ore.

Total 79.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting. Any member or Associate objecting to the election of any of these candidates should so inform the Secretary before June 25.

9510 Coolidge, W. D., Schenectady, N.Y
9511 Dyer, L. L., Redondo Beach, Cal.
9512 Fleming, S. W., Jr., Newburgh N.Y.
9513 Hall, C. I., Chicago, Ill.
9514 Parker, F. I., Milwaukee, Wis.
9515 Roop, K. C., Philadelphia, Pa.
9516 Schmidt, A. R., Milwaukee, Wis.
9517 Watson, T. S., Milwaukee, Wis.
9518 Woodhull, F. H., Coatesville, Pa.
9519 Fox, A., Chicago, Ill.
9520 Hudson, R. G., Boston, Mass.
9521 Campbell, A. C., Walla Walla, Wash.
9522 Estberg, H. C., Greeley, Colo.
9523 Jeffery, J. J., Toronto, Ont.
9524 Reisbach, G. B., Milwaukee, Wis.
9525 Waldron, R., Jr., Los Angeles, Cal.
9526 Barnes, A. H., Columbus, Ohio.
9527 Barron, A. N., Cleveland, Ohio.
9528 Bloch, A., New York City.
9529 Blocksidge, G., Pittsburg, Pa.
9530 Brown, H. F., New Haven, Conn.
9531 Dempsey, G. T., Philadelphia, Pa.
9532 Downie, J. W., Christchurch, N. Z.
9533 Ehrlich, H., Chicago, Ill.
9534 Francis, H. R., Anderson, Ind.
9535 Heidtmann, A. W., New York City
9536 Hill, L. S., Ann Arbor, Mich.
9537 Jones, N., Dunedin, N. Z.
9538 Maynard, C. T., Proctor, Vt.
9539 Perry, R. H., Knoxville, Iowa.
9540 Jones, H. H., San Diego, Cal.
9541 Kemp, J. T., Findlay, Ohio.
9542 Lindemann, F., Cordoba, A. R.
9543 Matheson, W. B., Los Angeles, Cal.
9544 Mullegrey, A. L., Poteau, Okla.
9545 Reyes, C. T., Corozal, P. R.
9546 Stottler, E. J., Cement, Texas.
9547 Vreeland, F. P., Schenectady, N. Y.
9548 Walker, T. P., Toronto, Ont.
9549 Wortham, E., Richmond, Va.
9550 Brown, A. J., Milwaukee, Wis.
9551 Dorn, W. G., Chicago, Ill.
9552 Griswold, A. H., San Francisco, Cal.
9553 Hansen, K. H., St. Louis, Mo.
9554 Miller, E. B., Ione, Wash.
9555 Yerger, C. H., Milwaukee, Wis.
9556 Shute, Nathan, Philadelphia, Pa.
9557 Staunton, C. S., Hartwick, N. Y.
9558 Roth, F. H., Ensenada, P. R.
9559 Bacon, F. R., Milwaukee, Wis.
9560 Bryden, T.W., Binghamton, N.Y.
9561 Maujer, R. I., Milwaukee, Wis.
9562 Browning, H. L., Ft. Wayne, Ind.
9563 Carbutt, R. F., N. Y. City.
9564 McNiece, T. M., Cleveland, Ohio.
9565 Moultrop. I.E., Boston, Mass.
9566 Wackwitz, E. F., Cleveland, Ohio.

Total 57.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners at its regular monthly meeting held on May 17, 1910. Any objection to the transfer of these Associates should be filed at once with the Secretary.

MILTON ULMER, general attorney and engineer, Schondube & Neugebauer, Mexico City, Mexico.

BRENT WILEY, commercial engineer, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

WILLIAM ARTHUR THOMAS, commercial engineer in sales department, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

HAROLD PENDER, professor of theoretical and applied electricity Massachusetts Institute of Technology, Boston, Mass.

V. ALFRED FYNN, consulting engineer, St. Louis, Mo.

ROBERT PAYNE FAIRBANKS, in charge of preparation for research work of Telluride Institute at Cornell University, Ithaca, N. Y.

JAKOB EMIL NOEGGARATH, consulting engineer, New York.

Students Enrolled, May 17, 1910

3663 Berssenbrugge, B., Univ. of Wis.
3664 Desloge, L. F., Purdue Univ.
3665 Du Bois, T. R., Univ. of Penn.
3666 Erickson, N. F., Mass. Inst. of Tech
3667 Fancher, F. J., Syracuse, Univ.

3668 Finke, W. J., Univ. of Minnesota.
3669 Hansell, D. R., Univ. of Penna.
3670 Johnson, L. T., Univ. of Minn.
3671 Josephson, E. B., Univ. of Minn.
3672 Kenney, W. D., Kansas State Univ.
3673 McCoy, L. E., Univ. of Oregon.
3674 O'Neal, J. P., Carnegie Tech. School.
3675 Perkins, H. R., Univ. of Michigan.
3676 Poindexter, P. W., Rose Poly. Inst.
3677 Sanborn, H. D., Mass. Inst. of Tech.
3678 Snyder, T. I., Purdue Univ.
3679 Twisden, H. S., Mass. Inst. of Tech.
3680 White, J. F., Penn. State College.
3681 Anderson, C. B., Jr., Purdue Univ.
3682 Beery, E. J., Univ. of Washington.
3683 Benham, H. M., Case School Science.
3684 Bonnett, L. B., Syracuse Univ.
3685 Boyd, S. G., Case School App. Science.
3686 Brown, A. T., Penn. State College.
3687 Dull, A. W., Purdue University.
3688 Durgen, M. F., Mass. Inst. Tech.
3689 Ellis, G. E., Jr., Tufts College.
3690 Fitzsimmons, J. T., Case School.
3691 Freund, O. A., Univ. of Michigan.
3692 Gehm, C. S., Case School.
3693 Goldsborough, J., Univ. of Col.
3694 Gould, A. A., Mass. Inst. Tech.
3695 Grover, H. G., Case School Science.
3696 Harding, A. L., Mass. Inst. Tech.
3697 Hopkins, R. A., Univ. of Wash.
3698 Jesperson, C. M., Univ. of Minn.
3699 Johnson, J. R., Univ. of Wash.
3700 Keller, C. C., Inter. Corres. School.
3701 Koehl, L. L., Case School Science.
3702 Matter, O. E., Iowa State College.
3703 Moore, E. B., Mass. Inst. Tech.
3704 Mowry, C. J., Univ. of Nebraska.
3705 Nelson, C. H., Univ. of Minnesota.
3706 Ogden, L. E., Worcester Poly Inst.
3707 Orwig, D. C., Case School Science.
3708 Peabody, G. A., R. I. State Coll.
3709 Pilsbury, C. C., Worcester Poly. Inst.
3710 Robertson, E. A., Univ. of Col.
3711 Ryder, R. W., Univ. of Cal.
3712 Schirmer, A. H., Case School
3713 Schmidt, F. L. A., Case School.
3714 Shelton, E. K., Univ. of Wash.
3715 Shields, R. A., Univ. of Mich.
3716 Sipher, E. F., Case School Science.
3717 Snell, T. W., Stanford, Univ.
3718 Steelquist, R. U., Cornell, Univ.
3719 Sterling, J. D., Univ. of Illinois.
3720 Stump, J. H., Rose Poly. Inst.
3721 Thomas, R. P., Case School.
3722 Tompkin, W. I., Iowa State Coll.
3723 Welsh, J. T., Univ. of Wisconsin.
3724 White, H. L., Univ. of Nebraska.
3725 Zabriskie, E. B., Univ. of Mich.

Total 63.

Section Meetings

Boston

At a meeting of the Section on April 9, 1910, in the auditorium of the Edison Building, Mr. Harold S. Osborn presented a paper on "Potential Stress in Dielectrics." Professor D. C. Jackson presided; there were present 27 members and visitors.

The Boston Society of Civil Engineers held its regular monthly meeting in Tremont Temple, Boston, Mass., on Wednesday evening May 20, 1910, in coöperation with the Boston Section of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers. Over 300 members of the three organizations were present. Mr. Frederick H. Newell, of Washington, D. C., director of the U. S. Reclamation Service, delivered a lecture entitled "Engineering Work of the Reclamation Service." The lecture was well illustrated by colored lantern slides showing proposed reservations and the various irrigation works with which the service has been connected, notably, the Roosevelt Dam, the Yuma Dam, the Gunnison Tunnel, Jackson Lake, the Boise River, and the Yellowstone, Truckee, Missouri, North Platte and Shoshone enterprises.

On April 27, 1910, there was a meeting conducted by the American Society of Mechanical Engineers in the auditorium of the Edison Building, Professor I. N. Hollis presiding. Professor C. M. Allen presented a paper on "Testing of Water Wheels after Installation."

Chicago

A joint meeting of the Chicago Section with the Electrical Section of the Western Society of Engineers was held

at Chicago on January 26, 1910. Mr. W. B. Jackson, of the W. S. E., was the presiding officer, but resigned the chair to Mr. J. G. Wray, chairman of the Chicago Section. Mr. Wray then introduced Mr. W. Lee Campbell, of the Automatic Electric Company, who presented a paper on "Recent Development in the Automatic Telephone." An excellent collection of lantern slides and a demonstration of the automatic apparatus, added greatly to the interest of the paper.

Another joint meeting of the two organizations was held on February 23, 1910. Professor P. B. Woodworth presided. At this meeting Mr. Edward N. Lake, secretary of the Chicago Section, presented a paper entitled, "Some Suggested Improvements in Underground Conduit Construction for Large Transmission Systems." The paper was discussed by Messrs. D. W. Roper, W. B. Jackson, Baird, Darling and G. B. Springer.

On the evening of April 27, 1910 the Section held another of its regular joint meetings with the Electrical Section of the Western Society of Engineers in the rooms of the Society of Chicago, Mr. J. G. Wray presiding. The paper of the evening was presented by Mr. William B. Jackson upon the subject of "Depreciation and Reserve Funds of Electrical Properties." Mr. Jackson treated the topic upon the basis of the following outline and definitions:

"The term depreciation as here used may be divided into two parts:

1. *Decrepitude*. Which covers the gradual wearing out of the apparatus from the effects of use and of age, which cannot be overcome by current repairs, and which results eventually in ending the operative life of the apparatus.

2. *Obsolescence*. Which takes into account the reduction in the useful life of apparatus, on account of advances in the art whereby otherwise operative apparatus is made uneconomical for further use.

The term reserve fund, as here used, may also be divided into two parts:

1. *Required Reconstruction*. Which takes into account reconstruction costs made necessary by municipal or other legislative requirements.

2. *Special Insurance*. To cover expenses that cannot be forecast with any degree of certainty, caused by extraordinary occurrences such as unusual storms, explosions, great conflagrations, acts of strikers, etc."

An evidence of the keen interest in this subject was shown by the large number of discussors, the principal interest centering upon the question of depreciation.

Mr. Ralph W. Pope, Secretary of the Institute, who had earlier in the evening addressed the Lewis Institute Branch, Chicago, was introduced by the Chair toward the close of the discussion and spoke briefly concerning his western trip, his present trip to the coast and also discussed the question of maintenance with reference to the Engineers' Building in New York. There was a total attendance of 103.

Ithaca

A regular meeting of the Section was held in Rockefeller Hall, Ithaca, on Friday, May 6, 1910, at which Professor H. T. Plumb of Purdue University gave an experimental lecture on "High Frequency, High Voltage Phenomena." Professor H. H. Norris presided, and there was a total attendance of 300. Professor Plumb illustrated by a complete equipment of apparatus, some of the more spectacular effects of electricity, such as are met with in problems of lightning protection, surges in transmission lines, etc.

Milwaukee

The second meeting of the Milwaukee Section was held at the Plankinton House, Milwaukee, on Wednesday, April 13, in coöperation with the Engineers' Society of Milwaukee. President Watson, of the Engineers' Society, pre-

sided. Dean F. E. Turneaure, of the engineering college of the University of Wisconsin, presented a paper entitled "Experiments to Determine the Stresses in Bridges Caused by Locomotives Running at High Speed." The experiments and tests described in the paper had been made by the maintenance-of-way departments of various railroads, and involved the design and manufacture of special "deflectometers" to measure the deflection of the bridges, and "extensometers" for measuring the extension of special bridge members. The results obtained indicated that the allowance made in current practice for impact loads on railroad bridges is, in general, ample, and in many cases unnecessarily large, especially for long spans. An interesting fact brought out was that for each bridge there was a critical speed for any particular engine at which the natural period of vibration of the bridge and the impact from the unbalanced engine drivers are in synchronism and the extent of the deflection is much magnified. On short spans reduced speed may be necessary, but on long spans the critical speed may be so low that the impact at such speed is well within safe limits. The total attendance at the meeting was 82 members of both societies.

Philadelphia

Preceding the evening meeting of May 9, 1910, 30 members of the Section were taken over the works of the New York Shipbuilding Company, at Camden, by Mr. H. A. Horner, electrical engineer of the company. In the evening Mr. Horner gave a talk on the subject of shipbuilding with special reference to the use of electricity on shipboard, which was discussed by Messrs. Spencer, Painter, Costa, Green and Hoadley. Mr. G. A. Hoadley presided and there was a total attendance of 44.

Pittsburgh

The Section held a banquet at the Fort Pitt Hotel, Pittsburgh, on Friday, April 8, 1910, with Mr. C. B. Auel as toastmaster.

The speakers of the evening and the titles of their respective addresses were as follows:

"Pittsburgh Section," Mr. Charles F. Scott; "The Institute," President Lewis B. Stillwell; "The Relation of the Public Service Corporation to the Public," Malcolm C. Rorty; "A Little Leakage—More or Less High Tension," George C. Johnston; "Insulation," Dr. Walter Riddle.

There were present 330 among which were included many ladies. A feature of the evening was the singing of popular songs interspersed among the toasts. The committee on arrangements consisted of: Messrs. C. B. Auel, Chairman; W. Edgar Reed, Bertrand P. Rowe, Ludwig Hommel, R. A. L. Snyder, H. N. Muller, W. E. Moore, E. B. Tuttle.

Portland Oregon

The April meeting of the Section was held in the Electric Building, Portland, on April 19, 1910, L. B. Cramer, local secretary presiding. There was an attendance of 27. A committee was appointed to suggest to the Building Code Committee of Portland certain necessary changes in the proposed Building Code in regard to the requirements of the chief electrical inspector and his deputies.

Mr. W. M. Hoe then presented a paper on "The Electrical Installation of a Modern Quartz Mill," after which Mr. Paul Lebenbaum abstracted Dr. Cary T. Hutchinson's Institute paper on "The Electrification of the Cascade Tunnel of the Great Northern Railway."

Seattle

A regular meeting of the Seattle Section was held at the Central Building, Seattle, on April 16, 1910. No regular paper was presented, but, having been previously requested to do so by the chairman, salesmen representing different manufacturing companies gave

a series of short talks on Three-Wire Direct-Current Generators, which brought forth some interesting discussion regarding the advantages of the three-wire machine as compared with the balance system. Mr. A. A. Miller presided and there was a total attendance of 21. Professor Magnusson extended an invitation to the Section to hold its next meeting at the University of Washington and this invitation was accepted. There will be an inspection of the new laboratories of the University, a dinner, and a dance.

Toledo

At a meeting of the Toledo Section held in the parlors of the Y.M.C.A., Toledo, on Friday, May 6, 1910, Mr. Harry Sprong spoke on the wiring involved at telephone central stations, as well as upon apparatus at such stations, and the apparatus of a wireless signalling set was used for demonstration purposes. The installation of a wireless station was also illustrated by sketches. After the demonstrations the members and visitors in attendance adjourned to the United Wireless Station in Toledo where the apparatus in operation was still further explained. The attendance at the meeting, at which Mr. George E. Kirk, presided, numbered 20.

Toronto

A special Industrial Power meeting was held by the Section on Friday, April 15, 1910, at the rooms of the Engineers' Club, Toronto. Over 50 members were present and Mr. E. Richards presided. The paper of the evening was presented by Mr. John C. Parker of the Rochester Railway and Light Company, on "Industrial Power Work." He pointed out particularly that the industrial engineer's duties involved general economics of manufacturing and business, rather than the mere sale of motors or power, as the case may be, and made a strong plea for a higher standard of ethics in the engineering profession, both on the part of the industrial engineer attached to the operating company and also on the part of the consulting engineer. The following men participated in the discussion that followed: Messrs. J. E. Bullard, A. S. L. Peaslee, Robert Greenaius, W. R. Sweeney, N. S. Braden P. W. Sothman, W. A. Bucke.

Washington

The April 12, 1910 meeting of the Section was addressed by Mr. E. P. Rowe on the subject of "Illumination." There were present 73 members and visitors, Mr. Philander Betts presiding. Mr. Rowe illustrated his remarks by lantern slides and explained the methods of determining distribution curves from various sources. He pointed out the relation between total flux of light and the intensity on different directions in a vertical plane, and exhibited a number of typical reflectors and globes, demonstrating in actual trial their action in concentrating the radiation in particular directions or in diffusing it over specific zones.

The resignation of Mr. Morton G. Lloyd as Secretary was announced and Mr. H. B. Stabler was appointed to fill out the unexpired term. Mr. Lloyd has been appointed Technical editor of the *Electrical Review and Western Electrician* and is now in Chicago.

Branch Meetings

University of Arkansas

The members of the University of Arkansas Branch met in the engineering hall of the university on the evening of April 19, 1910. Mr. C. M. Moreland gave an account of a trip that he made to Joplin and Pittsburgh for the purpose of obtaining data for thesis work. Mr. R. E. Thompson described the water power survey trip recently made by the senior electrical engineering students. The main feature of the evening was a paper by Mr. W. B. Stelzner, in which he told of his experience while with the General Electric Company. Mr. Stelzner gave a general description of the Schenectady works and showed many views of the machinery, tests and shops.

Armour Institute of Technology

At the regular meeting of this Branch held in Chapin Hall on April 7, 1910, Mr. Arthur Bessey Smith, of the Automatic Electric Company, read a paper on "The Automatic Telephone from the Commercial Standpiont." In his opening remarks Mr. Smith gave a brief resume of the conditions which led to the invention and introduction of the telephone, and pointed out its importance in the business and social economy of the world at the present time. He then analyzed the telephone situation as a business proposition, with a view to determining its weak points, also outlining its development to the present stage of perfection. Mr. Smith laid particular stress on the advantage of eliminating the human element, as far as possible, from all operations of a mechanical nature, and pointed out how this was being accomplished by the automatic exchange. He took the view that whatever operation can be performed by machinery, it can be done better and more uniformly and cheaply than by hand, on the principle that a properly designed machine performs its operations in obedience to a law from which it cannot deviate. It would therefore appear that the automatic exchange must be more accurate than a system depending upon manual operation, provided that the machine does the work uniformly and does not get out of repair. This latter feature, he stated, though at first regarded with some misgiving, has not given serious trouble. It was pointed out that automatic switches which in some cases have been in use for nine years are yet in perfect condition. The cost of repair parts per telephone year was given as from one and a half to two and a quarter cents. An analysis of the total cost of service in the manual and automatic systems showed a balance in favor of the automatic.

University of Colorado

This Branch held its regular meeting on April 6, 1910. Thirty-nine members were present. Mr. William Trudgian, a graduate of the university, class of 1907, gave a talk on his experience with the Westinghouse Electric and Manufacturing Company. Mr. Trudgian is at present connected with the company's Denver office.

Colorado State Agricultural College

A meeting of the Colorado State Agricultural College Branch was held in the electrical engineering building Fort Collins, on Friday, April 15, 1910, with E. J. Falloon presiding. Mr. Guy Phelps lead the discussion on the Institute paper "Hydroelectric Power as Applied to Irrigation" presented by Mr. John C. Hays at the San Francisco meeting of the Institute.

At the meeting on April 29, 1910, Mr. R. Proctor discussed the Institute paper by Mr. W. Lee Campbell on "Modern Automatic Telephone Apparatus" presented at New York.

State University of Iowa

The April meeting of this Branch was held in the engineering building of the university on April 25, 1910. Professor Arthur H. Ford delivered a lecture on "Radio-Telegraphy," of which a practical demonstration was given.

At the meeting on May 9, 1910, Mr. H. J. Hagendorn abstracted the two Institute papers on Electric Power from Central Stations presented by D. C. Jackson and R. S. Hale at Boston, February 16, 1910.

University of Kansas

The University of Kansas Branch held its regular meeting on April 27, 1910. Mr. Ernest Weibel addressed the members on "An Induction Generator." Mr. Weibel described the results of some tests on an induction generator, which were performed by himself and Mr. Fred Winter as thesis work.

Lehigh University

The May meeting of this Branch was held in the physical laboratories of Lehigh University on May 10, 1910. Mr. W. W. Broadbent presided. The papers of the evening were: "Trunk Line Electrification" by Mr. W. S. Murray, and "The Starting of Single-Phase Induction Motors" by Mr. W. W. Broadbent. The guests for the evening included Mr. John Fritz and Mr. R. P. Stevens.

Lewis Institute

Mr. Ralph W. Pope, of New York, Secretary of the A.I.E.E., was the guest and speaker at the meeting of the Lewis Institute Branch held on April 27, 1910, and addressed the 250 members and students present on the subject of "Education of the Electrical Engineer." Mr. Pope brought out many points which in a large measure control the ultimate success of an engineer, making special mention of the importance of a thorough knowledge of the English language.

University of Maine

The University of Maine Branch held its regular meeting on April 20, 1910, with a total attendance of 22 members. Professor C. W. Thompson gave a lecture on "The German System of Education."

There was a meeting of the Branch on May 4, 1910 at which Mr. A. T. Childs presided and there was a total attendance of 20 members. A paper on "Power Plant Test at Dover, Maine" was presented by Mr. Charles Smith based on the Institute paper on "An Imperfection in the Usual Statement of the Fundamental Law of Magnetic Induction," (Transactions A.I.E.E., Vol. XXVII), by Mr. H. M. Royal.

University of Missouri

At the meeting of the University of Missouri Branch on April 11, 1910, Mr. E. B. Miller discussed the subject of "Electricity in Mining." The subject was treated under the following heads: Processes for gold extraction; electric hoists and electric winding; underground working; signaling; lighting. The saving of power and the decrease in cost in the mills for gold extraction where electric drive had been installed was brought out strikingly by some figures for a particular installation which showed a reduction of fuel consumption from 2,630 lb. to 848 lb. In addition to this there was an equally notable reduction in water consumption—an important item of cost in this field. The great improvements that have been made in hoisting machinery were pointed out, and also the superiority of the electric hoists over all other types. Underground working is still done principally by compressed air, notwithstanding its low efficiency. The mine locomotive and the electric cutter are, however, being used to a considerable extent in the larger coal mines. Low voltage signaling systems were described and attention called to their advantages in allowing multiple signals to be given and return calls to be made. The paper concluded with a description of the primitive methods employed for lighting, the candle and miner's lamp still being widely used, and also described the recent application of low voltage tungsten lamps operated by storage batteries.

The annual election took place at the meeting of the Branch held on April 25. The following officers were elected for the year 1910–1911: Chairman, H. B. Shaw; secretary, Alan E. Flowers; executive committee, E. W. Stapf and J. S. Haddaway. The two members of the executive committee were empowered to select a third member. Mr. G. B. Randall then presented Dr. Samuel Sheldon's paper on "Education for Leadership in Electrical Engineering." In the discussion of the paper Professor Shaw spoke of the advanced requirements for entrance to the courses in engineering at the

University of Missouri, and of the value of a thorough general training. In speaking of the general lack of facility in the use of English, Professor Shaw recommended wide reading of good authors as one of the best methods for a preliminary training in the use of good English, and that report writing, speaking at meetings, and preparing papers for the student publications were also excellent aids.

Montana State College

On April 22, 1910, 20 members of the Montana State College Branch visited the substation of the Madison River Power Company and the power plant of the Gallatin Valley Electric Railway Company. Prior to this trip a brief business meeting was held at which arrangements were made for the Branch's third annual electrical show to be held during the latter part of May.

University of Nebraska

A meeting of the University of Nebraska Branch was held in the university on May 4, 1910, Professor George H. Morse presiding. Mr. C. G. Throckmorton, division construction engineer for the Bell Telephone Company in Omaha, presented a paper on " Telephone Engineering in Small Towns." Mr. Throckmorton explained the methods used in making the " House Count," and also gave consideration to the principles of laying out a cable distribution with regard to the economics of materials, first cost and maintenance, giving instances of personal experience where engineering principles had been neglected and comparing the results obtained with those derived from good engineering.

New Hampshire College

The New Hampshire College Branch held a meeting on April 13, 1910. Mr. Wilfred Sykes' paper on " Large Electric Hoists " was reviewed by Mr. E. D. French, all of the members present taking part in the discussion.

Another meeting was held on April 27, 1910, in the college club rooms. The subject discussed was " Machine Tool Drive ", and its various phases were discussed by Professors F. E. Cardullo, C. E. Hewitt, and Mr. T. A. Thorp. Professor Cardullo showed the advantages of electrical over mechanical drive. Professor Hewitt showed the adaptability of certain types of motors for driving certain types of machines. Mr. Thorp reviewed a number of Institute papers on electric motor application, and the installation of new motor-driven tools. Twenty-three members were present at the meeting.

Oregon Agricultural College

At the April 25th meeting of this Branch Professor T. M. Gardner reviewed Dr. S. Sheldon's Institute paper on " Education for Leadership in Electrical Engineering," presented in New York. Messrs. J. D. Carnegie and L. M. Harris jointly presented a paper on " The Electric Furnace and Furnace Processes," being the fifth of a series of papers on electrochemistry.

Purdue University

The Purdue University Branch held a meeting in the university on March 22, 1910, with Mr. O. W. McIndoo presiding. There was a total attendance of 109, and Mr. A. B. Smith of the Automatic Telephone Company gave a review of Automatic Telephony.

The meeting of April 19, 1910 was addressed by Mr. E. A. Wagner of the Fort Wayne Electric Works on " Some Engineering Features of Transformer Design," illustrated by lantern slides and sketches. There was an attendance of 72 at this meeting. Mr. Wagner gave a brief history of transformer design showing by curves the progress made in the past. He indicated in a general way the improvements which

may be expected in the future, and stated that he considered the selection and arrangements of the materials, especially of the iron and insulation, to be the elements most vital to a successful design.

Syracuse University

A meeting of the Branch was held in the university on May 12, 1910, Mr. W. P. Graham presiding. Mr. E. M. Wharff, of the Rochester, Syracuse and Eastern Railroad, spoke on "Construction and Maintenance of Overhead Work on Electric Railroads," describing the transmission systems and the pole and catenary constructions used on the "Beebe Roads," mentioning some of the difficulties that had been encountered and the improvements made.

Washington University

The Washington University Branch held a meeting in the university on the evening of May 3, 1910, Mr. H. F. Thomson presiding. Professor A. S. Langsdorf gave an illustrated lecture on "Niagara Falls and Its Power Developments," opening with a description of the falls and surrounding country. He gave in detail the various power projects which have from time to time been carried out at and near the falls.

Worcester Polytechnic Institute

A regular meeting of the Branch was held in the Polytechnic Institute on Friday, April 22, 1910 at which Professor A. S. Richey gave a talk on "Accidents and Incidents." Mr. R. H. Taber presided and the attendance totalled 175. Professor Richey cited many instances of catastrophes and incidents, that had come to his attention. After the talk, refreshments were served and music dispensed by the Tech orchestra.

Bucknell University Branch Established

At its meeting on May 17, 1910, the Board of Directors of the Institute on recommendation of its Sections Committee authorized the organization of a Branch at Bucknell University, Lewisburg, Pa., to be known as Bucknell University Branch. The authorization of this Branch makes a total of thirty-one regularly organized and active Branches of the Institute.

A Report of the International Congress for Testing Materials

Copenhagen Sept. 7–11, 1909

To the President and Board of Directors of the A.I.E.E.:

Sometime last summer the writer had the honor of being appointed by President Ferguson, a delegate of the Institute to the International Congress for Testing Materials, to be held in Copenhagen September 7–11, 1909.

The opening day of the Congress found the writer, one of almost a thousand members, in the Festival Hall of the University of Copenhagen, listening to the cordial and appreciative words of welcome with which His Royal Highness, Crown Prince Christian of Denmark, opened the Congress, and to the beautiful music dispensed by a choir of students of the University.

This opening ceremony signaled the beginning of a very busy week. The programme for the Congress was a very ambitious one, comprising a morning and afternoon session each day; an excursion to some place of scientific, technical or general interest later in the afternoon; and a reception, dinner, or entertainment each night.

The arrangements were in every way excellent. The meetings were all—with the exception of the opening one—held in the Town Hall, which had been placed at our disposal by the city authorities, by whom everything was done to make the Congress feel at home. The work was divided into three sections: *A*, Metals; *B*, Cement; and *C*, Other materials. The writer attended principally the meetings of Section *A* (metals), where he had the privilege of listening to very interesting discus-

sions between such eminent metallurgical authorities as Mr. Stead of England, Professor le Chatelier of France, Geheimrat Martens of Germany, and the late Dr. Dudley and Dr. Moldenke of America.

The writer will not attempt to report any of the business transacted, but will refer instead to the official report of the Congress, in which he desired particularly to call attention to the papers by Mr. Ew. Rasch of Gr. Lichtesfelde dealing with the use of electrical methods in the testing of materials, and by A. Gruenhut and Dr. J. Wahn of Vienna on the changes of magnetic and electrical properties of metals undergoing a strain; and last, but not least, to the paper by Professor Pierre Weiss of Zurich on changes in magnetic properties of alloyed steels.

Among the places of interest visited were the laboratories of the Polytechnic Institute, of which particularly the electrical ones have equipment that is unusually complete and well designed; and the combined refuse destruction and electric plant of the municipality of Frederiksberg, which according to all reports is quite successful, the output being disposed of mainly for light and power in a large municipal hospital in the immediate vicinity, where also the exhaust steam is utilized for heating purposes.

Copenhagen, with vicinity, is at present undergoing a period of very active electrical development. The city depends for its electrical supply on a system of municipal steam-driven central stations, furnishing direct current at 240-480 volts (three wire system). Originally only the central portion of the city was supplied with electricity, which was generated in two or three direct-current stations at above voltage, the stations being interconnected, but lately the area of distribution has been increased considerably, forcing the central station to go over to alternating-current generation and transmission.

The present idea is to generate at 50 cycles, 4400 volts, three phase, and to gradually transform the present steam plants into motor generator sub-stations serving their districts as heretofore with 240–480 volts direct current. One of the reasons for this lies in the fact that the street car system is supplied with power through the municipal mains from standard street car generators at 550-volt direct current, and this arrangement enables the municipal stations to get along with a minimum of reserve street car generator capacity, since obviously, any of the standard 480-volt generators may be used for street car service in an emergency.

This scheme has been successfully used for a number of years, but while it has added to the arguments in favor of retaining the direct-current system for the central portion of the city, it has not prevented the adoption of alternating-current distribution, partly underground, but very largely on pole lines, for the outlying districts.

The writer had occasion to visit most of the central stations in Copenhagen and vicinity, and found that while the older direct-current installations naturally followed the German practice of the nineties, the newer plants, in spite of the use of generators and much other apparatus of Continental make, were remarkably close to the newest and most approved American practice.

Plans are now under way for a very ambitious scheme of municipal supply, involving the building (on made land with deep water facilities) of a steam-driven turbine station, having an ultimate capacity of 200,000 kw., which will, of course, make no difference in the scheme of distribution being only a logical outcome of the development.

In the municipalities immediately adjoining Copenhagen, the adoption of alternating current is also causing large extensions of present systems, and development of new ones. Denmark has been remarkably backward in electrical development heretofore, and it is therefore very interesting to watch the present activity.

Among the other things of interest

to the electrical fraternity the writer might perhaps mention the telephone system, which is just now being "Americanized" by the introduction of the common battery system; and the street cars of Copenhagen, which give excellent service. The ideal of "a seat for everybody" seems actually to have been attained, principally by the extensive use of trailers during rush hours, and double-decked cars on some of the lines having the heaviest traffic morning and night.

The writer presents this report, hoping that what seemed interesting to him may also prove of some interest to others engaged in similar work.

Respectfully submitted,
(Signed) ODDGEIR STEPHENSEN.

Threatens Engineers' Building

A project for the opening of a new avenue midway between Fifth and Sixth Avenues, New York City, and paralleling those thoroughfares from 14th to 59th Streets is being discussed. The proposed avenue would pass directly through the Engineers' Building. Although the plan is tentatively approved by Mayor Gaynor, it will not be seriously considered until thoroughly investigated. Chief engineer Nelson P. Lewis has already suggested a route which will avoid the demolition of most of the important buildings, including the property of United Engineering Society, in which the Institute holds an equity of approximately $530,000.

Advanced Study of Electrical Engineering at Massachusetts Institute of Technology

Some interesting facts are being brought out by investigations of the effect of high voltages on insulating material by Mr. H. S. Osborne who is carrying out work for the degree of Doctor of Engineering at the Massachusetts Institute of Technology. At a recent meeting of the Boston Section of the American Institute of Electrical Engineers which was held at the electrical engineering laboratories of the Institute of Technology, Mr. Osborne lectured on the results of his experimental research.

The lectures of Professor Harold Pender for graduate students will next year extend the discussion contained in his advanced lectures of this year on the high voltage alternating transmission and utilization of power. The general treatment of the transmission circuit contained in his lectures of this year will be repeated and extended and more attention will be given to the conditions arising from the utilization of the power.

Professor Jackson's lectures for graduate students on the organization and administration of public service companies have this year dealt more particularly with questions of value of plant, the theory of so-called intangible values, the relation of revenues to value of the plant, depreciation, and the like; and next year the lectures will be directed more to the theory underlying methods of charging for service by public service companies, with particular reference to charges for electric light and power but with collateral consideration of railroad and tramway charges and charges for gas and the service of other public utilities.

Professor Wickenden will originate a course of lectures on illumination, photometry and illuminating engineering which will become a part of the optional curriculum for undergraduate and graduate students.

Personal

MR. JULIUS HERMANN has accepted a position with the Potosina Electric Company at San Luis Potosi, Mexico.

MR. JOHN W. THOMPSON has been appointed general manager of the Potosina Electric Company, San Luis Potosi, Mexico.

MR. DAVID D. GIBSON is now connected with the Electric Storage Bat-

tery Company of Philadelphia, in the drafting room.

MR. E. G. HOWARD, formerly of the Chicago office of the General Electric Company is now in the Minneapolis office of the same company.

MR. RICHARD C. M. CALVERT, formerly assistant chief electrical engineer with the Mysore Government, India has returned to America.

MR. LEWIS A. SHREWSBURY, formerly with the El Oro Mining and Railway Company is now connected with the Mexican Light Heat and Power Company.

MR. C. C. CONDON has been engaged as erecting engineer during the construction of the Seymour Gas and Electric Light Company's new plant at Seymour, Indiana.

MR. W. I. BOLEN, formerly in the construction department of the General Electric Company is now with the Mexican Light and Power Company, Mexico City, Mexico.

MR. JAMES M. GAGEN, has left the employ of the New York Edison Company and has taken a position with J. Livingston and Company as assistant to the electrical engineer.

MR. GEORGE O. BAKER, formerly with the New England Engineering Company has opened offices at 35 Wall Street, New York, as a consulting and supervising engineer.

MR. W. C. WAGNER, electrical engineer for the Northwestern Improvement Company at Roslyn, Wash., has been appointed master mechanic and electrical engineer for its properties at Ravensdale, Wash.

MR. E. R. HILL assistant chief engineer of electric traction and station construction, P. T. & T. R.R. Company is now located in the new Pennsylvania Station at 32nd Street and 7th Avenue, New York City.

MR. LINN B. ABBOTT, electrical engineer, Yarmouth, Mass., has accepted position as engineer-in-charge of Harvey Hubbell, Inc., Bridgeport, Conn. He still maintains his practice as electrical engineer.

MR. T. F. FOLTZ, inspector on improvements in the Sunnyside yard of the Pennsylvania Tunnel and Terminal Company has been transferred to the Pittsburgh division of the P. R.R. as assistant electrician.

MR. F. M. WELLER, formerly with Stanbrough and Grant, consulting engineers, Norfolk, Va., is now engaged in industrial engineering work with the Consolidated Gas, Electric Light and Power Company of Baltimore, Md.

MR. E. H. LE TOURNEAU has resigned his position in the electric power department of the N. Y. C. & H. R. R.R. Company and has accepted a position as superintendent of the Exchequer Mining and Power Company, Exchequer, Cal.

MR. W. H. RUDISILL of the Southern Traction and Power Company, Burlington, N. C., has accepted a position with the Alabama Power Development Company and for the present is in New Orleans; his headquarters will be at Anniston, Ala.

MR. GEORGE GIBBS, chief engineer of electric traction and station construction, Pennsylvania Tunnel and Terminal Railroad Company is now located in his new offices in the Penn-

sylvania Station at 32nd Street and 7th Avenue, New York.

Mr. Henry L. Davisson who was assistant sales manager of The Westinghouse Storage Battery Company up to the time of its dissolution has recently accepted a position in the sales department of The Edison Storage Battery Company, New York.

Mr. Ira C. Walborn has recently left the employ of the Eastern Pennsylvania Railways Company on his appointment as assistant electrical superintendent of the Eastern Pennsylvania Light, Heat and Power Company, at Pottsville, Pa.

Mr. James H. Smeaton in charge of operation at the Lac Du Bonnet generating station of the Winnipeg Electric Railway Company for the past four years has left that company and is now in charge of operation for the Pennsylvania Water and Power Company, McCall Ferry, Pa.

Mr. H. N. Muller has recently been appointed superintendent of distribution of the Allegheny County Light Company of Pittsburgh, Pa. Mr. Muller has been associated with this company for the past eleven years and since 1905 has been its electrical engineer.

Mr. Norman B. Hickox has resigned his position as manager of new business for the S. S. Bush syndicate and has accepted a position with H. M. Byllesby Company, Chicago, as manager of new business for the Muskogee Gas and Electric Company, Muskogee, Okla.

Mr. R. E. Wagner, has resigned his position as superintendent of testing department of the Canadian General Electric Company, Peterboro, Ontario, and is now assistant to the technical superintendent, General Electric Company, Schenectady, N. Y.

Mr. Wm. A. Turbayne, formerly electrical engineer with the Gould Coupler and Gould Storage Battery companies has been appointed special engineer in connection with storage battery and car lighting work, for the United States Light and Heating Company of Maine, with offices at Buffalo.

Mr. Edward P. Decker for many years engineer with Westinghouse, Church, Kerr and Company, has associated himself with Mr. Ernest M. Baker, under the firm name of E. P. Decker and Company. The company will conduct a general engineering and construction business with offices at 80 Griswold Street, Detroit, Mich.

Mr. Victor J. Radbone, formerly in construction office of the General Electric Company at Atlanta, Ga., has recently returned from Rugby, England where he was engaged on the commercial engineering staff of the British Thomson-Houston Company, and is at present in the power and mining engineering department of the General Electric Company at Schenectady, New York.

Dr. Robert B. Owens, formerly professor of electrical and steam engineering, University of Nebraska, professor of electrical engineering, McGill University, Montreal, and electrical engineer for The Southern Power Company, Charlotte, N. C., has recently been appointed Secretary of the Franklin Institute, Philadelphia, Pa. Dr. Owens is a member of the American Society of Mechanical Engineers, a Member and past vice-president of the American Institute of Electrical Engineers, a member of the Institution of Electrical Engineers, a member and past president of the electrical section of the Canadian Society of Civil Engineers.

Obituary

TOWNSEND WOLCOTT, a former member of the Board of Directors, and for about ten years a member of the Board of Examiners of the Institute died of pneumonia in Brooklyn, N. Y., April 29, 1910. Mr. Wolcott was elected an Associate of the Institute March 6, 1888 and was transferred to the grade of member December 16, 1890. He was elected a Manager for the term 1902–5 and a Vice-president 1905–7. He had

TOWNSEND WOLCOTT

been an active factor in Institute affairs throughout his association with it, and his judicial temperament, and strict integrity were thoroughly appreciated by his colleagues. Mr. Wolcott was born in New York City, July 18, 1857, and although his education was confined to the common schools of that era, he was throughout his life an earnest student, and was conspicuous for his thorough familiarity with public affairs, as well as his practical grounding in mechanical and electrical engineering. He had made a specialty of the study of physics and mathematics, which was of great service to him in his professional career. He was associated with several of the pioneer electrical companies from 1879 to 1888 having been a laboratory assistant of Edward Weston with the United States Electric Lighting Company; electrician with the Julien Electric Traction Company, having charge of storage batteries and motors in street car work; the Mutual Electric Company as designer of electrical apparatus; and the new American Electric Arc Light Company, constructing ammeters and voltmeters. That he profited in his training by this varied experience was shown in his papers, articles, and discussions. As early as 1886 he presented papers before the New York Electrical Society "On the Theory of Magneto Electric Induction as applied to the Gramme Ring" and on "What is Electricity," the latter having been printed in the *Electrical World* and the *Electrician* (London). Through his efforts the first self-exciting dynamo built in the United States, by Professor Charles A. Seeley was presented to the Institute in 1893 accompanied by a descriptive paper by Mr. Wolcott entitled "An Early Dynamo" proving that it was constructed in 1867, in New York City. Mr. Wolcott was a most conscientious man in whatever he undertook. He could be relied upon as doing his duty, and as an officer, or a member of a committee faithfully gave his best thought and closest attention to his Institute work. At the time of his illness and subsequent death he was in the employ of the government as electrical engineer of the United States Signal Corps in New York City. The nature of this work was such that he could not draw upon it for that class of papers in which the electrical engineers of the day are especially interested. At the New York meeting, May 28, 1902 he presented a paper on "Submarine Cable Testing in the Signal

Corps, U. S. A." which was a notable contribution in that comparatively limited but important field of American electrical practice. In discussion and criticism his thoughts were based on logical grounds, and whatever differences of opinion may have existed, none could doubt his sincerity. Those who recall the early struggles in the gradual upbuilding of the American Institute of Electrical Engineers can the more thoroughly grasp the calls of necessity, which brought out the best qualities of so loyal a supporter. It was through this unselfish and enthusiastic assistance that Mr. Wolcott gained the friendship of his co-workers, and to those who formed his acquaintance during this period, the news of his untimely death was especially depressing. To have gained the esteem of all with whom he was associated was in itself a fitting tribute to a life of well-doing.

WALTER C. KERR died at Rochester, Minnesota on May 8, having started West for treatment about two months ago. He was born in St. Peter, Minnesota on November 8, 1858, entered Cornell at the age of 17 and graduated in the mechanical engineering course in 1879. For one year he was instructor and later became assistant professor, which position he held for two years. After going with the Westinghouse Machine Company as salesman and rising to manager of their eastern sales office, Mr. Kerr in 1884 helped to organize Westinghouse, Church, Kerr and Company, being made treasurer. Later, he was made vice-president, and finally president, in which capacity he served up to his death. Mr. Kerr became an Associate of the Institute on January 25, 1907. He was also a member of the American Society of Mechanical Engineers, the Canadian Society of Civil Engineers and the Franklin Institute, besides numerous social and athletic associations. Mr. Kerr leaves a widow and four children.

RALPH F. ADAMS, with the General Electric Company at West Lynn, Mass., died suddenly on May 7, 1910, at his residence in Boston, Mr. Adams became an Associate of the Institute on June 29, 1909.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

L'Académie Royale des Sciences. Annuaire, 1910. Bruxelles, 1910. (Exchange.)

Agenda de l'electro. 1910. Bruxelles, 1910. (Gift.)

Care and use of the field artillery signal equipment (U. S. War Department. Circular No. 4.) (Exchange.)

Fields of Force. (Publication No. 1 of the Ernest Kempton Adams Fund for Physical Research, Columbia University) by V. F. K. Bjerknes. New York 1906. (Gift Dept. of Physics. Columbia University.)

Kelvin, Life of Lord. Vols. 1-2. By S. P. Thompson, London, Macmillan & Co., Ltd. 1910. (Purchase.)

Morse, S. F. B. Manuscript copy of his daily journal, containing the correspondence of Mr. Morse and the Secretary of the Treasury and others, relating to the installation of his original telegraph line. It also includes a description of his meeting with Mr. Bain, the inventor of the Bain alphabet. (Gift of Thomas A. Edison.)

National Physical Laboratory. Collected researches, Vol. VI, 1910. N.p. 1910. (Exchange.)

——Report 1909. Teddington, 1910. (Exchange.)

New York (State) Water Supply Commission. Annual report 5th. Albany, 1910. (Gift of State Water Supply Commission.)

Patent law Association. Brief on bills H. R. No. 18,885 and S. No. 5,636. Washington, 1910. (Gift.)

Royal Dublin Society. Economic Proceedings. Vol. 1-date. Dublin, 1899-date. (Exchange.)

——Scientific Proceedings. Vol. 12-date. Dublin, 1909-date. (Exchange.)

Street Railway Association of the State of New York Report of the 27th Annual meeting. New York, 1909. (Exchange.)

Telephony's Directory of the telephone industry of the United States, Canada and Mexico. The only directory of the telephone field, "comprising a list of over 16,000 independent operating telephone companies." Fifteenth year 1910. Chicago, Telephony Publishing Co., copyrighted, 1910. Price, $5.00.

CONTENTS: Alphabetical list of manufacturers and dealers; Classified list of articles made for telephone use; Index to advertisers; Number of telephone companies by States, according to companies size; Operating telephone companies of America; Tables, statistics, data, rules, weights, measurements and other information; Telephone associations and Officers.

Theory of electrons, and its applications to the phenomena of light and radiant heat. By H. A. Lorentz (Publication No. 2 of the Ernest Kempton Adams Fund for Physical Research, Columbia University) New York, 1909. (Gift Dept. of Physics Columbia University.)

TRADE CATALOGUES

Allgemeine Elektricitats Gesellschaft, Berlin, Germany. Aluminum cells as conductors of excess voltage 20 pp.

——Electric power in textile mills. 21 pp.

——Electric driving of looms. 20 pp.

——Electric narrow-gauge-locomotives for traction and industrial railways. 9 pp.

——Electric locomotives for suburban railways. 8 pp.

——Electric plows. 4 pp.

——Electrical driven reclamation service station at the mouth of the Maas river. 5 pp.

——Electrical driven threshing and chaff separating machines. 4 pp.

——Portable electric motors for agricultural use. 4 pp.

——Electric threshers. 4 pp.

——New controllers for electric railways 4 pp.

——Electrical motors for agricultural deep well pumps. 2 pp.

——Equipment of the power station at Besswitz and of the Besswitz Electrical Company's plant. 32 pp.

Bell Electric Motor Co., Garwood, N. J. Bull. 130—Bell automatic single phase repulsion induction motors. 7 pp.

Crocker-Wheeler Co. Ampere, N. J. Bull. No. 118. Form L direct current machines. 15 pp.

——Bull. No. 124—Exhaust fans. 3 pp.

——Generators for railway, power and lighting, motors and transformers for industrial service. 5 pp.

General Electric Co., Schenectady, N. Y. Price list No. 5214—G. E. Edison carbon incandescent lamps. 7 pp.

——Price list No. 5218—G. E. train lighting lamps. 3 pp.

——Mazda versus Tungsten lamps. 6 pp.

——Bull. No. 4716—Thomson Watt-hour meters with prepayment attachments for direct and alternating current. 7 pp.

——Bull. No. 4719.—General Electric fan motors and small power motors. 36 pp.

Pass & Seymour, Solvay, N. Y. Brass shell sockets for electric lamps. 15 pp.

Pettingell-Andrews Co., Boston, Mass. Catalogue of Sprague electric fans. 35 pp.

——Juice, March and April 1910, a publication devoted to the products of the Pettingell-Andrews Co. 16 pp.

Storrs Mica Co., Oswego, N. Y. Calendar of railroad club and association meetings and conventions, and list of members of the Railway Business Association. 4 pp.

Scully Steel & Iron Co., Chicago, Ill., 1910 Blue Book, being a catalogue of iron, steel, machinery, heavy hardware, tools and supplies, with valuable and accurate reference tables. 304 pp.

Walker Electric Co., Philadelphia, Pa. Electrical control and distribution of a modern department store. 12 pp.

Western Electric Co., Hawthorne, N. Y. Bull. No. 5111—Direct driven generators, type " LL." 12 pp.

——Bull. No. 5351—Alternating current motor-driven 42-inch Davidson propeller fan. 7 pp.

——Bull. No. 5500—Solaris arc lamps. 7 pp.

Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Circ. No. 1132—Lightning protective devices. 58. pp.

——Circ. No. 1170—Interpole railway motor No. 305. 23 pp.

——Circ. No. 1176—Electrically heated matrix driers. 7 pp.

——Circ. No. 1179—Series Tungsten lamp street lighting systems. 23 pp.

UNITED ENGINEERING SOCIETY

A. L. A. Portrait Index. 1906. Washington, 1906. (Purchase.)

Electric Power Plants. By T. E. Murray New York. 1910. (Gift of author.)

Engineering Index, 1909. New York, 1910. (Purchase.)

Iowa Board of Railroad Commissioners. Annual report 27th-31st, 1904–1908. Des Moines, 1905–1909. (Gift of Iowa Railroad Commissioners.)

Journal of Gas Lighting, Water Supply and Sanitary Improvement. Vols. 23–50, 51 (except Jan. 3, May 8, June 26 and index); 52 (except July 17, 24, 31 and index); 53–56 (except index); 58 (except index); 59 (except all of Jan. Feb. 2 and 16, all of March, April 12, May 3 and 31 and index); 60, (except Oct. 11, Nov. 1 and index); 61 (except June 13, 20, 27 and index); 64–79, 80 (except Oct. 14); 81 (except March 24); 82, 83 (except Sept. 1); 84 (except Oct. 27) 85–87, 89, 90 (except index); 91 (except July 11–Aug. 8, Aug. 22, Dec. 12); 93 (except Jan. 30, Feb. 6); 94–95, 96 (except Nov. 6); 97–98 (except indexes); 100, No. 2336. London, 1874–1907. (Gift of American Gas Institute.)

Nebraska State Railway Commission. Annual report 1st and 2d. Lincoln, 1908, 1909. (Gift of Nebraska State Railway Commission.)

New Hampshire Railroad Commission. Annual Report 65th 1909. Manchester, 1910. (Gift of New Hampshire Railroad Commissioners.)

New Pronouncing dictionary of Spanish and English Language. By M. Velazquez de la Cadena, New York, Appleton & Co., 1909. (Purchase.)

Ohio Railroad Commission. Report 1st and 3d Springfield, 1906, 1908. (Gift of Ohio Railroad Commission)

Poole's Index to Periodical Literature, Vol. 6, 1902–6. Boston, Houghton, Mifflin & Co., 1908. (Purchase.)

Schneider & Co., Paris, France. Automobile wheels manufactured. 9 pp.

——Creusot and manganese steel used in railway construction. 9 pp.

——Products and machinery manufactured by Schneider & Co. 19 pp.

OFFICERS AND BOARD OF DIRECTORS, 1909-1910.

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EDWARD WESTON, 1888–9.
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*WILLIAM A. ANTHONY, 1890–91.
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CARL HERING, 1900–1.
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SCHUYLER S. WHEELER, 1905–6.
SAMUEL SHELDON, 1906–7.
HENRY GORDON STOTT, 1907–8.
LOUIS A. FERGUSON, 1908–09.

*Deceased.

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A paper to be presented at the 242d meeting of the American Institute of Electrical Engineers, New York, January 14, 1910.

(*Subject to final revision for the Transactions.*)

ON THE SPACE ECONOMY OF THE SINGLE-PHASE SERIES MOTOR

BY WM. S. FRANKLIN AND STANLEY S. SEYFERT

It is not the object of this paper to argue for single-phase alternating-current electrification versus direct-current electrification, nor to argue for the locomotive versus the multiple-unit system of electric propulsion, nor to argue in favor of the axle motor as against the detached motor with side-bar or gear connections. The sole object of the paper is to discuss the question as to the maximum single-phase series motor rating that can be placed within a given space, and indeed the authors approach this question, not on an absolute basis, but on a basis of comparison. Given a well-designed single-phase alternating-current series motor of the usual construction, as represented, for example, by the motors of the present locomotives of the New York, New Haven & Hartford Railroad (and every one who has seen these motors in operation must admit that they represent a splendid achievement on the part of their designer) the question is how great an increase of rating can be realized by certain alterations in the design and by the use of certain new auxiliary devices. As will appear in the sequel, this question admits of a qualitative answer in every particular and of a quantitative answer in several important particulars.

A single-phase series motor differs from a direct-current motor:

1. Because its power-factor is less than unity.
2. Because of greater core losses and because of power loss due to short-circuit currents.
3. Because of a great tendency to spark at the commutator.

From the view-point of the operating engineer, however, these

differences may present themselves as a single difference as follows:

(*a*) For a given frequency and rating, satisfactory operation may necessitate a very bulky and expensive motor; or

(*b*) For a given size and rating, satisfactory operation may require the use of a very low frequency; or

(*c*) For a given size, given frequency, and given rating, it may be impossible to realize satisfactory commutation.

Thus it may be said that the disadvantage of the single-phase series motor lies either in its excessive size, or in the necessity of using extremely low frequency, or in the unsatisfactory character of commutation. If, however, we choose a frequency of 25 cycles and set ourselves to meet the condition of satisfactory commutation—and we must meet this condition in any case—then the disadvantages of the single-phase motor reduce themselves solely to the question of size and weight. It is from this point of view that the authors approach the discussion of the single-phase series motor in this paper.

In a recent paper by Messrs. L. B. Stillwell and H. St. Clair Putnam,* the single-phase series motor problem was reduced to a question of frequency, and from this point of view they reached the following conclusions:

> * * * * * consideration of the facts now available lead us to conclude that notwithstanding the number and force of the arguments in favor of 25 cycles, a frequency of 15 cycles is preferable and should be adopted for heavy electric traction. The fundamental and, as it would appear, controlling reason which leads to this conclusion is the fact that within given dimensions a materially more powerful, efficient, and generally effective single-phase motor can be constructed for 15-cycle operation than is possible if 25 cycles be selected.
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> * * * * *
>
> In the case of multiple-unit equipment of passenger cars where locomotives are dispensed with and motors carried upon the car trucks, it is very important that the dimensions of motors be reduced to a minimum.
>
> * * * * *
>
> In the application of single-phase commutating motors to locomotives in general railway service, the minimizing of motor dimensions is perhaps still more important, although in this instance the limitations imposed by the space available are less obvious.

In the following discussion of the possibilities of space economy of the single-phase series motor, frequent reference will be made

* *Transactions of American Institute of Electrical Engineers*, 1907, Vol. XXVI, Part I, pages 31–101.

to the present electrical equipment of the New York, New Haven and Hartford Railroad, and the authors take occasion at this point to express their conviction that the equipment as it stands meets all of the conditions originally specified by the railroad company. This conviction is based in part upon a somewhat intimate personal association of the authors with the engineers of the New York, New Haven and Hartford Railroad, and in part upon the published records of the construction and operation of the equipment. No one claims, however, that the New Haven electrification represents a complete and satisfactory solution of the problem of heavy trunk-line electric traction. Indeed the authors have been assured by the New Haven engineers that the present equipment leaves much to be desired in the wav of increase of motor-rating for a given weight of locomotive, especially an increase of tractive effort at starting. Mr. E. H. McHenry, for example, has not hesitated to state his opinion that greater and longer continued tractive effort, especially at starting, must be made possible without increase of weight.

Inasmuch as this paper refers almost wholly to matters of design, it is desirable to give a statement of the conditions which determine the design of a single-phase series motor.

(*a*) To produce a moderately large power-factor, and

(*b*) To reduce the tendency to spark at the brushes.

Consideration of Power-Factor

Fig. 1 is the well-known clock diagram in which I represents the current flowing through the motor, E the voltage acting across the motor terminals, $X_f I$ and $R_f I$ the reactance and resistance drops respectively in the field winding, $X_a I$ and $R_a I$ the reactance and resistance drops respectively in the armature and neutralizing windings combined, and E_c the induced counter electromotive force in the armature due to rotation. It is evident from this Fig. that a large power-factor (small value of the angle θ) depends upon a large value of E_c in comparison with $X_f I$ and $X_a I$. Of course $R_f I$ and $R_a I$ should both be as small as possible because they represent energy losses in the windings.

(*a*) In the first place the reactance $X_a I$ of the armature winding may be reduced nearly to zero by the use of the neutralizing winding.

(*b*) In the second place, consider the reactance drop $X_f I$ in the field winding. For a given frequency this is proportional

to the product of the number of field turns and the maximum value of the alternating field-flux, exactly as in the case of the primary coil of a transformer. Assuming that we have a motor in which a specified maximum flux is to be produced, then to make the reactance voltage $X_f I$ a minimum, the machine must be designed so that the desired field flux may be produced by the least possible number of field turns. That is to say, the reluctance of the magnetic circuit must be small; or, in other words, the gap-space between the pole faces and the armature core must be short, and the iron of the field magnet and armature core must be operated at a low degree of magnetic saturation.

In the third place, the value of E_c may be increased for a given value of speed and given value of field flux by increasing

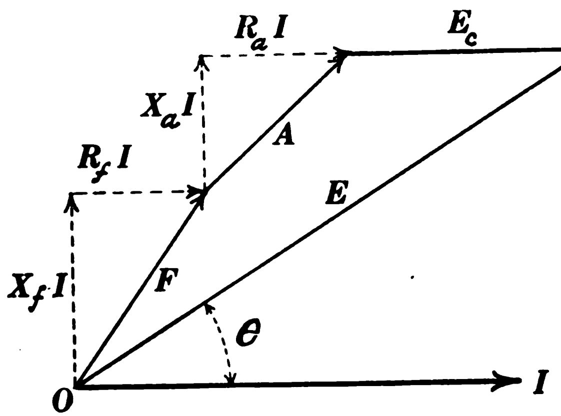

Fig. 1

the number of armature conductors. Therefore the use of a large amount of armature copper is an important feature of the single-phase series motor.

In the fourth place, suppose we have a single-phase series motor running at given speed with given value (effective) of current and given value (effective or maximum) of field flux. Under these conditions E_c is definite in value (effective), the mechanical power $E_c I$ is definite, and a reduction of the frequency produces a proportional reduction of the reactance voltages $X_f I$ and $X_a I$ without affecting the value of E_c; that is, a reduction of frequency increases the power-factor of the motor. Therefore it is important to use low-frequency alternating current for a single-phase series motor.

Consideration of Sparking

A number of undesirable effects are included in the general term of sparking, as follows:

(*a*) The effects that are present in a direct-current machine and which are due to the necessity of a quick reversal of the current in a given armature section as the terminal bars (commutator bars) of the section pass under a brush; and

(*b*) The effects that are present in the alternating-current machine due to the excessive current which is produced in each short-circuited armature section by the pulsations of the field flux.

The first effect is quite familiar to designing engineers and need not be discussed here.*

The effects of excessive short-circuit currents due to pulsations of field flux are: to heat the armature winding; to heat the commutator; to heat the brushes; and to roughen the commutator by sparking. The remedy for these undesirable effects is of course to prevent excessive short-circuit currents and to shorten their duration as much as possible.

The electromotive force induced in a short-circuited armature section by the pulsating field flux is proportional to the number of turns of wire in the section, proportional to the maximum value reached by the pulsating field flux, and proportional to the frequency. Therefore the short-circuit current may be reduced by reducing the number of turns of wire per armature section—the resistance of the short-circuit not being reduced in proportion to the turns because of the relatively large resistance at the brush contacts—by reducing the maximum value of the pulsating field flux, and by reducing the frequency. It is essential, therefore, in the design of the single-phase series motor to provide for few turns of wire per armature section (many commutator bars); to provide for small field flux per pole (many field poles); and to use alternating current of low frequency.

The duration of short-circuit of an armature section by a brush is proportional to the thickness of the brush, and therefore it is desirable to use thin brushes. If the armature winding is of the simplex type, the necessary thickness of the brushes is determined solely by the necessary area of brush-contact to

* A good discussion of this subject is given in a paper by W. L. Waters, *Transactions American Institute of Electrical Engineers*, 1904, Vol. XXIII, pages 365-378.

collect the given current. If the winding is of the multiplex type, a brush must never touch fewer than n commutator bars, where n is the number of constituent windings in the multiplex winding. In the multiplex winding, however, adjacent commutator bars do not form terminals of an armature section, and therefore the mere touching of two bars by a brush does not short circuit an armature section of a multiplex winding.*

Special Devices for the Prevention of Sparking

The foregoing discussion refers to those general features of design which tend to reduce short-circuit currents in the arma-

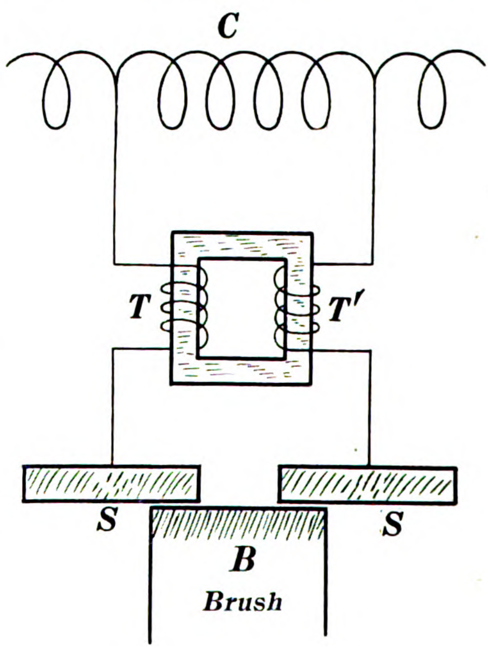

Fig. 2

ture sections of a single-phase series motor. It does not seem to be possible, however, to produce a single-phase series motor that will operate satisfactorily, without the use of special devices for the prevention of excessive short-circuit currents. The simplest device for this purpose is the insertion of a moderate amount of resistance in each commutator lead. This device is well known and need not be further discussed. A number of special inductive devices have also been proposed, and perhaps

* It would be out of place here to discuss in detail the short-circuits which occur in a multiplex winding.

the best of these is the balanced choke-coil arrangement of S. S. Seyfert.

The essential features of the Seyfert arrangement may be seen in Fig. 2 in which C is a section of the armature winding, S S are two commutator bars and T and T' are two coils on a small iron core. The two coils T and T' are so connected that their magnetizing actions on the iron core are equal and opposite when equal currents flow into (or out of) the armature winding through both coils; whereas their magnetizing actions work together when current tends to flow out of the armature winding through one coil and into the armature winding through the other coil. The resultant effect is that current can flow into or out of the armature through both coils T and T' without

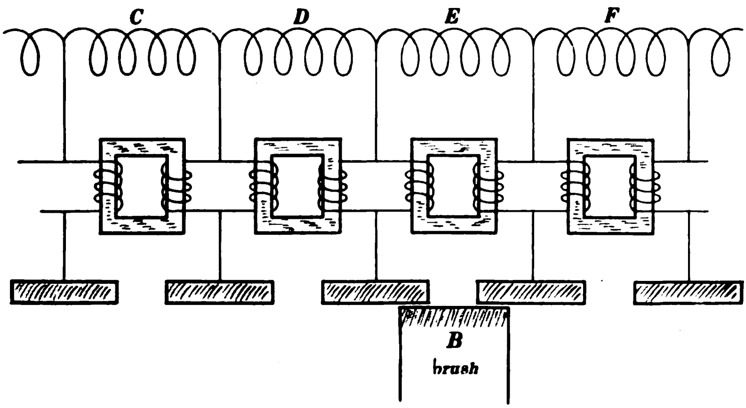

FIG. 3

being choked, whereas opposite currents in the coils T and T' (due to the short-circuit current in the section) are greatly choked.

Complete arrangement of the balanced choke-coils for a simplex armature winding are shown in Figs. 3 and 4. Fig. 3 shows what the authors call the single-span connection which requires the use of narrow brushes, and Fig. 4 shows the double-span connection,* which permits of the use of a broad brush.

In order to test the efficacy of the balanced choke-coil arrangement, it was applied to a single-phase series motor which

* Several distinct arrangements of the double-span connection are possible with a simplex winding, and a greater number of arrangements are possible with a multiplex winding. Ssome of these arrangements are much better than others.

was constructed and tested by Messrs. J. H. Wily and Geo. S. Mervine in 1905.† For the armature of this motor an old 25-h.p., 500-volt, Walker, direct-current, railway motor armature was used without any alterations except the addition of the system of choke-coils. The armature winding was a four-pole simplex wave, and it had three turns per armature section; that is, six turns between adjacent commutator bars. The commutator contained 97 segments. The armature core was 12.5 in. in diameter and 8.5 in. long. Two identical armatures were purchased, one to be used with and the other without balanced choke-coils. Fig. 5 shows the rosette of choke-coils nearly completed, and Fig. 6 exhibits the dimensions of the iron core

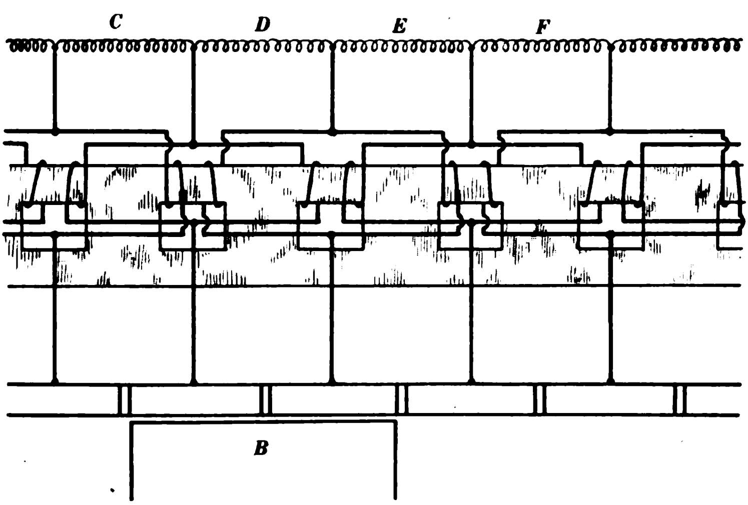

FIG. 4

structure. Each coil contained eight turns of No. 18 B. & S. copper wire. A general view of the completed armature is shown in Fig. 7. The field structure of this experimental motor was made* in the approved form with compensating windings placed in slots in the pole faces.

The ordinary speed, torque, and power-factor curves were determined for this motor as shown in Fig. 8. These tests were made with 30-cycle current from an old style high-fre-

† See graduating thesis in Department of Electrical Engineering of Lehigh University.

* All of the sheet-iron stampings were made by Messrs. Wily and Mervine, dies being especially constructed for the purpose.

quency alternator driven at about one-quarter speed. It was found impossible to maintain full voltage throughout the test; in fact the pressure ranged from 275 volts when the current input was 23.2 amperes to 260 volts when the current input was 35.2 amperes.

The pressure between adjacent commutator bars near the brushes was 19 volts effective when the motor current was 31.8 amperes, and yet the commutation was entirely satisfactory; even with a motor current of 35.2 amperes no more sparking was

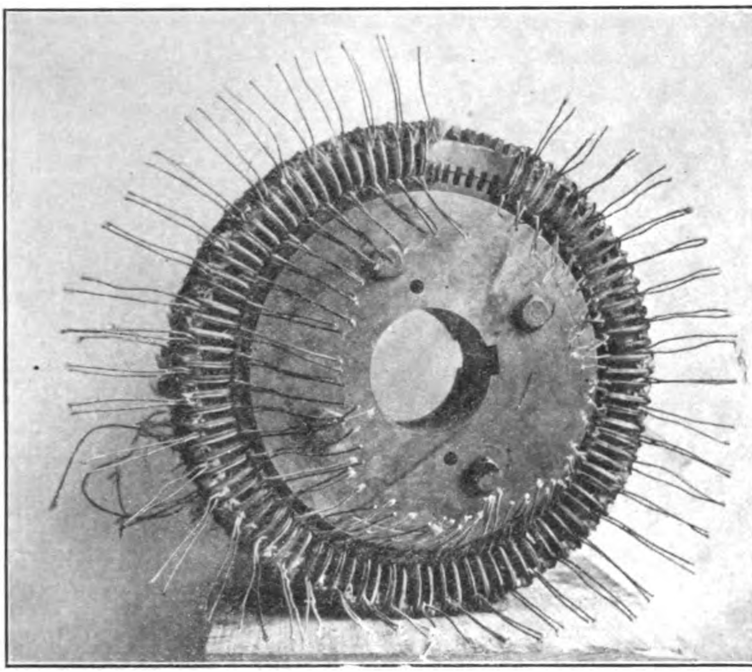

FIG. 5

in evidence than is usual on a direct-current motor of the same size. Indeed the commutator was in perfect condition after a long series of test runs. A single and momentary trial of the armature without the choke-coils exhibited a superlative degree of sparking, as was to be expected.

THE INVERSION OF FIELD AND ARMATURE IN THE SINGLE-PHASE SERIES MOTOR

In the direct-current motor the field should be much stronger magnetically than the armature and it should, therefore, be the

external member to give room for the field windings; in the alternating-current commutator motor, however, the armature must be the preponderating member and it should, therefore, be the external member to give room for the armature windings. An internal-rotating-field external-stationary-armature type of direct-current dynamo was brought out a number of years ago in England, but this type of direct-current machine is now entirely discredited both practically and theoretically. The internal-field external-armature type of single-phase series motor, however, presents very great advantages as follows:

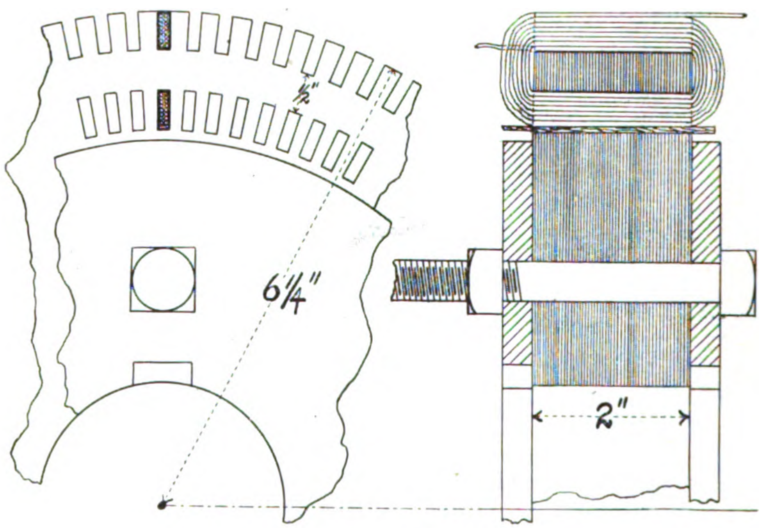

Fig. 6

(*a*) It presents more available space for the windings.

(*b*) It makes possible a material shortening of the end-connections of the compensating windings without lengthening the end-connections of the armature windings.

(*c*) It makes possible the removal of all non-sparking devices from the motor region proper, relieving the designer of every limitation in the use of resistance leads or other non-sparking devices except the limitation of cost and weight; and

(*d*) It makes possible the detaching of the commutator and the utilizating of the large amount of space ordinarily occupied by the commutator for motor iron and motor copper.

What may at first sight appear to be a disadvantage in the

detaching of the commutator is the necessity of driving the brush mechanism by gearing, but the transmission of the power required for this purpose does not present a serious problem; indeed, it would seem that the advantage of having the commutator and brushes always in view and always easily accessible would counterbalance any mechanical disadvantage involved in the detaching of the commutator.

Figs. 9 and 10 represent sectional views of two single-phase series motors having the same external and internal dimensions. Fig. 9 represents the ordinary design with internal armature and external field, and Fig. 10 represents the new design with internal field and external armature. The following table ex-

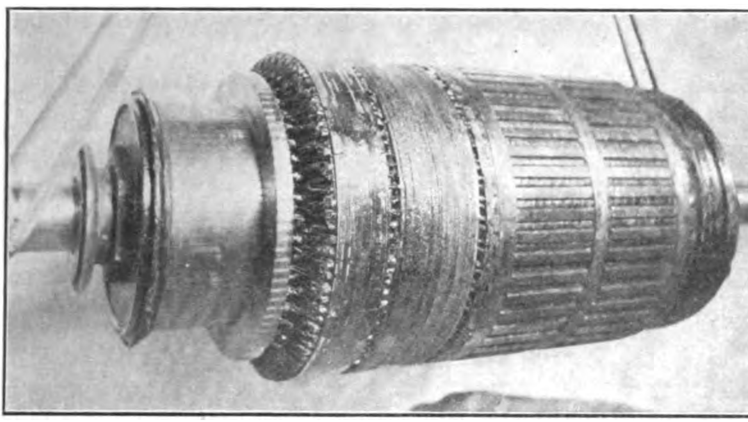

Fig. 7

hibits the details of dimensions, weights, losses, and efficiencies of these two machines according to the designs of S. S. Seyfert, and according to the independent calculations of Comfort A. Adams of Harvard University, and of A. S. McAllister. The core loss in the armature is calculated in each case as if it were due to the full-load flux density at normal primary frequency. In fact, armature core losses are somewhat larger than this.

These calculations are substantially in agreement, and they show a remarkable difference in rating of the two types of machine. The internal-field external-armature type of machine has a rating which is approximately 20 per cent in excess of the rating of the external-field internal-armature type of machine.

TABLE I

COMPARISON OF INTERNAL AND EXTERNAL FIELD SINGLE-PHASE MOTORS OF SAME SIZE

	Adams		McAllister		Seyfert	
	New type	Old type	New type	Old type	New type	Old type
Outside diameter, inches	30	30	30	30	30	30
Inside diameter, inches	10.75	10.75	10.75	10.75	10.75	10.75
Net length of iron	15.3	15.3	15.3	15.3	15.3	15.3
Full load speed, rev. per min	550	583	550	576	550	576
Horse power at above speed	156.7	130.7	157.1	129.1	160.5	131.5
Efficiency at full load, per cent	88.4	89.5	89.9	89.5	91.1	89.8
Power-factor at full load, per cent	81.3	77.2	78.2	77.8	76.9	73.
Full-load current	432	432	432	432	432	432
Terminal electromotive force	372	327	387	318.5	386	330
Electromotive force between adjacent segments of commutator at brush	10	10	10	10	10	10
Weight of copper, total	894	824	888	850	881	846
Weight of copper per h.p.	5.7	6.3	5.65	6.59	5.5	6.45
Weight of iron, total	1767	1781	1737	1659	1757	1742
Weight of iron per h.p.	11.3	13.6	11.1	12.8	10.9	13.2
Total weight of active material	2661	2605	2626	2510	2639	2589
Total weight of active material per h.p.	17	20	16.7	19.4	16.5	19.7

Removal of Non-Sparking Devices from the Motor Region Proper

After having been led to the external-armature internal-field type of construction for the single-phase series motor, the authors realized the very great advantage to be obtained by removing the resistance leads, or other non-sparking devices, from the motor region proper. These advantages are:

1. That resistance leads and balanced choke-coils, for example, can be used regardless of the amount of space they occupy so that the advantages to be gained by the use of such devices may be pushed to the limit, thus enabling the designer to produce a machine which commutates satisfactorily with a higher short-circuit voltage than would otherwise be possible.

2. The power losses in the non-sparking devices take place outside of the motor region proper and do not therefore have to be taken care of by ventilation.

3 Repairs to resistance leads, or other devices for preventing sparking, may be made with the greatest of ease and without opening up the motor in any way; and

4 Arrangements can be provided for the short-circuiting of any portion of the resistance leads or the disconnecting of the choke-coils at any prescribed motor speed, thus enabling the designer to treat the problem of starting and the problem of steady running independently of each other.

Removal of Commutator from Motor Region Proper

Another great advantage secured by the adoption of the external-armature internal-field type of construction is the possi-

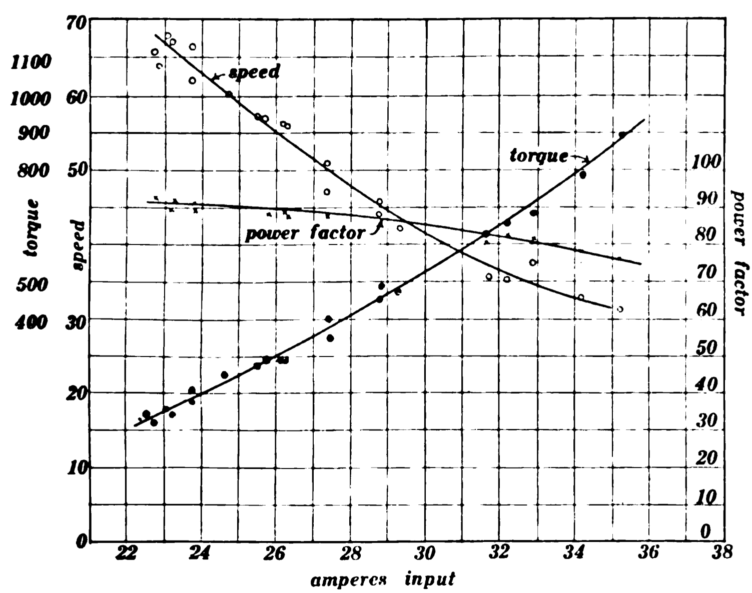

Fig. 8

bility of removing the commutator from the motor region proper and the consequent possibility of utilizing the motor region solely for motor iron and motor copper. This change alone represents a possible increase of about 60 per cent in the motor rating that can be placed in the region occupied by the motors of the New York, New Haven and Hartford locomotives, and it has the further advantage that the commutator losses occur outside of the motor region proper, thus simplifying the problem of ventilation.

A 500-H.P. Direct-Connected, 25-Cycle, Single-phase Series Motor Between 62-Inch Drivers

The authors have worked out in succession the more important details of design of five single-phase series motors in their

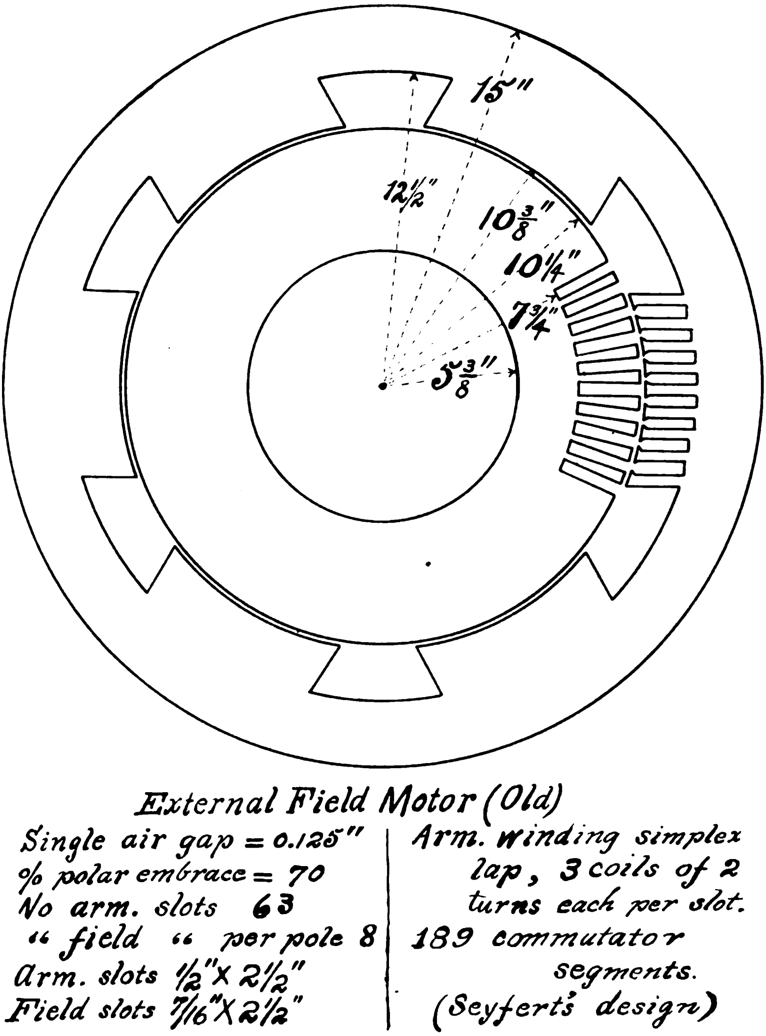

Fig. 9

application to the principles set forth in this paper. The last of these studies in design related to a 25-cycle motor to be placed between 62-in. drivers on a standard gauge locomotive. This

motor is referred to as motor No. 5. Fig. 11 is an outline sketch of this motor; *F F* is the internal rotating field and *R R* the collector rings for leading current into and out of the field and compensating windings; *Z Z* are the end-connections of

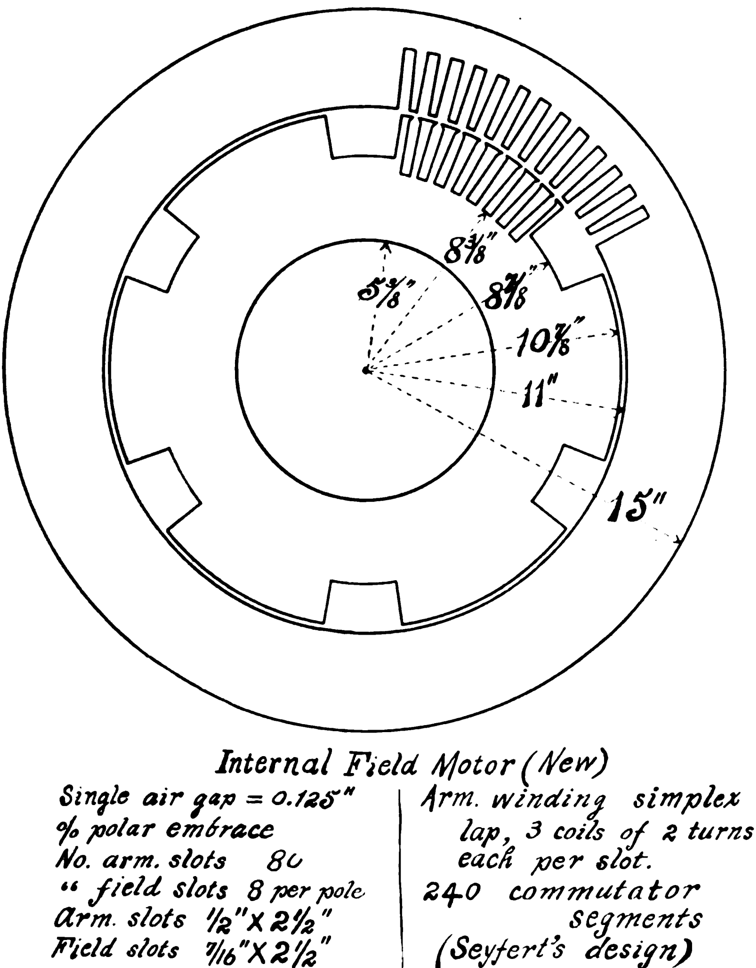

FIG. 10

the compensating windings, *A A* is the external stationary armature, *C C* the detached commutator, *S S* the rotating-brush arms which carry the brushes *B B*, and *R′ R′* the collector rings for supplying current to the rotating brushes. The axis of the com-

mutator is vertical, and the commutator is represented as being a hollow cylinder with the commutating surface on its interior. The brush shaft is supposed to be supported by arms which project forwards and backwards in the Fig. to the front and back parts of the motor casing; these supports are not shown in Fig. 11. The stamping dimensions of armature and field are shown in Fig. 12. Immediately above the commutator and surrounding the commutator lugs *L L* a set of terminal bars are to be pro-

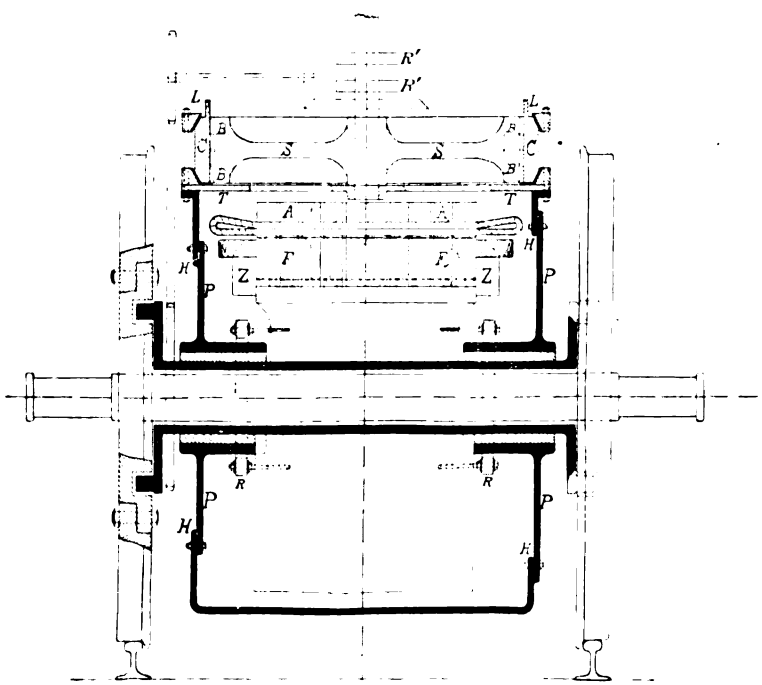

FIG. 11

vided to which the armature leads are to be connected, and the resistance leads and balanced choke-coils are to be connected between these terminal bars and the armature lugs and placed in any convenient position in the locomotive cab.

Provision is made for removing the internal field for repairs by sliding it out endwise. The details of this arrangement are shown with sufficient clearness by the holes *H* in the two ends of the motor casing, and the plates *P* which cover these holes; the left-hand driver in Fig. 11, being provided with a detachable

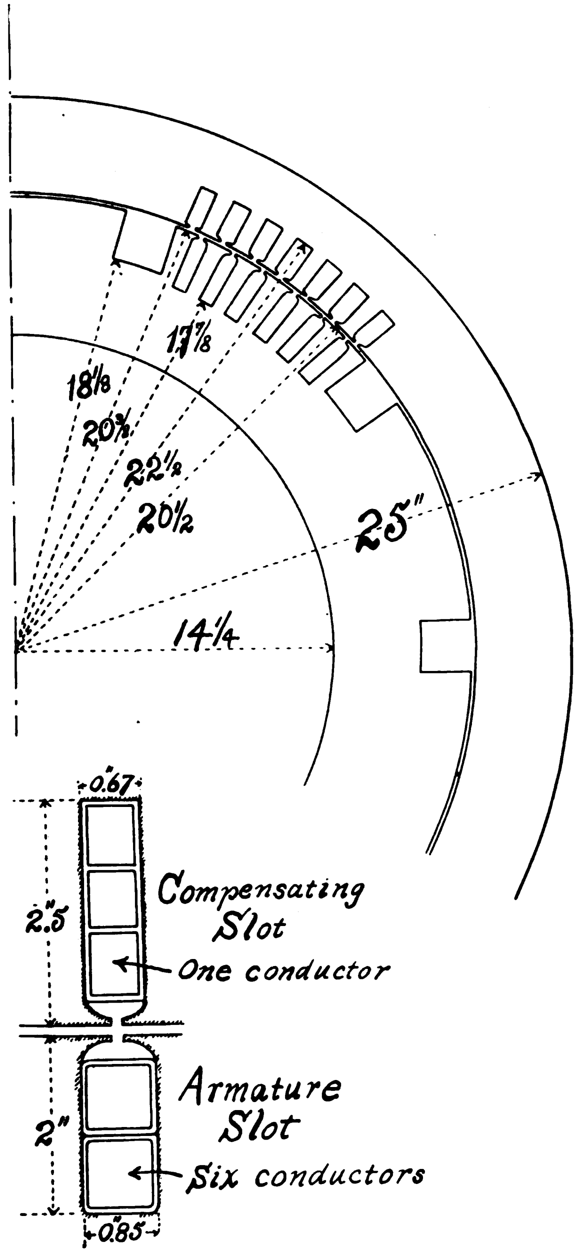
18⅛
20⅜
22½
20½
17⅞
25"
14¼
0.67"
2.5"
Compensating Slot
One conductor
Armature Slot
2"
Six conductors
0.85"

FIG. 12

rim so that what remains of the driver when the rim is detached can pass through the armature of the motor.

It was decided to adopt a 10-pole field instead of a 12-pole field as in the present New Haven motors. This decision was reached on the basis of a conviction that satisfactory commutation can be accomplished with 12 volts between commutator bars at the brushes by the free use of non-sparking devices which is permitted by the internal-field external-armature type of construction.

The more important items of design of motor No. 5 are here collected to give a better idea of the machine.

TABLE II

Gross motor length, $39\frac{3}{16}$ in.
Net length of iron, 21.46 in., which leaves 12 in. for end-connections and for 9 ventilating ducts each $\frac{3}{8}$-in. wide.
Outside diameter of motor, 50 in.
Terminal voltage of motor at full load and 45 miles per hour, 216.7 volts.
Full-load current, 2400 amperes.
Counter electromotive force at full load and 45 miles per hour, 154.8 volts.
Mechanical power developed in armature at full load, 380 kw. or 509 h.p.
Power-factor at full load, 76.8 for air-gaps of $\frac{1}{4}$-in. total.
Power-factor at full load, 83.1 for air-gaps of $\frac{3}{16}$ in. total.
Armature copper loss, 6010 watts.
Field copper loss, 1655 watts.
Compensating copper loss, 5140 watts.
Field core loss, 5940 watts.
Armature core loss, 7746 watts (calculated for full frequency and full-load density).
Total stator loss, 13,756 watts.
Total rotor loss, 12,735 watts.
Total power dissipated in motor space, 26,491 watts.
Electrical efficiency, neglecting commutator losses, 0.937.
Voltage between commutator bars near brushes, 12 volts effective.
Commutation constant corresponding to effective value of full-load current, 0.947 (equals reaction electromotive force per armature section during reversal of current at commutation).
Armature winding duplex lap with 1008 inductors.

A paper presented at a meeting of the San Francisco Section of the American Institute of Electrical Engineers, San Francisco, Cal., October 29, 1909.

(Subject to final revision for the Transactions.)

SOME PHASES OF TRANSFORMER REGULATION

BY W. A. HILLEBRAND AND S. B. CHARTERS, JR.

The following paper is based upon experiments conducted at Stanford University during the past two years upon the regulation of transformers under varying conditions. The first test was made upon a single phase, 200 watt, 11,000-110 volt meter-transformer. Owing to the importance of voltage and phase regulation in such a transformer, particularly when applied to the measurement of a large amount of power, a knowledge of its behavior in this regard is extremely desirable.

The remaining tests were made upon power transformers variously connected to polyphase networks, for the purpose of determining the cause and probable extent of the unbalancing in polyphase connections that occur under certain conditions.

The connections investigated were:

Three-wire, two-phase system of distribution.

Open delta.

Scott two-phase to three-phase transformation.

Inasmuch as any transformer in a group feeding into a polyphase network behaves precisely as it would when operated from a single-phase circuit under similar conditions of load and power-factor, the performance of the group of transformers is to be explained on the basis of the performance of their individual units as single-phase apparatus.

In Fig. 1 are shown regulation curves for a 4-kw. single-phase transformer operating at unity power-factor, and at 70 per cent power-factor leading and lagging.

Fig. 2 shows the relation between primary and secondary electromotive forces in the single-phase transformer with a 1:1 ratio, considered as a simple impedance connected across the

circuit. The fact we wish principally to emphasize by means of this diagram is that the impedance of the transformer causes not only a variation in the amount of secondary voltages but also a displacement in phase.

With leading current the secondary electromotive force is displaced more than if the power-factor were unity, and still more than if the current were lagging. This general relation is shown in Fig. 3.

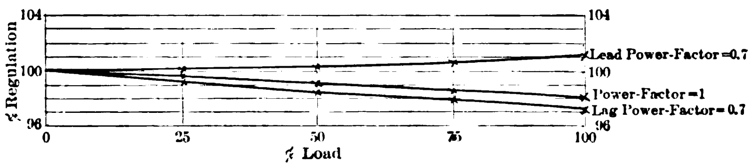

FIG. 1

Meter-transformer. Since in most installations special transformers are inserted between the power mains and the instruments, the accuracy with which the power is measured depends not only upon the inherent accuracy of the instruments but also upon the regulation, both voltage and phase, of the transformers. Thus, if the secondary pressure of the meter-transformer is lower than it should be, due to loading, the power recorded will be less than the real value. Also, if the phase-angle between

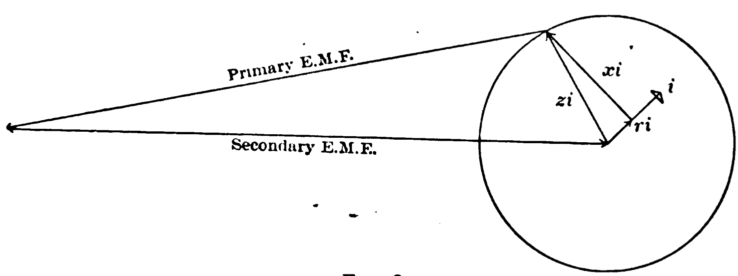

FIG. 2

the currents in the pressure and field coils of the meter differs from that between line pressure and current, a second error is introduced.

It is well known that meter pressure transformers are provided additional secondary turns to compensate for the drop due to loading, so that when used at their specified load they give their rated voltage ratio; and to give this ratio the load should be as nearly as possible that for which the transformer is com-

pensated. It is comparatively easy in this way to compensate for voltage-drop at any given power-factor, but this will not compensate fully for the drop at a different phase relation between current and electromotive force.

Theoretically it should be possible, by making the resistance very large in proportion to the reactance, to design a transformer of perhaps poor voltage regulation at unity power-factor but one which would give nearly the same drop over a range of power-factors much less than unity.

FIG. 3

An effort to accomplish this end might have been made in the transformer tested, in which the dimensions are as follows:

Ratio of turns—100; 1 approximately.
Primary resistance = 5900 ohms.

Primary resistance in secondary terms	= 0.59	ohms.
Secondary resistance	0.306	"
Equivalent resistance	= 0.896	"
Impedance, in primary terms	0.9824	"
Impedance, in secondary terms	0.9824	"
Equivalent reactance	= 0.406	"

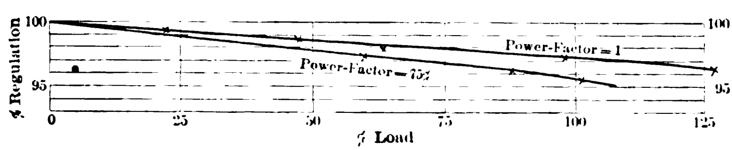

FIG. 4

Voltages—11,000 to 110.
Capacity—200 watts.
Full-load secondary current = 1.82 amperes.

This shows an equivalent resistance of somewhat over twice the equivalent reactance, proportions entirely different from those in the ordinary power transformer, but in spite of this fact the voltage-drop varies widely with the power-factor, as shown by the curves in Fig. 4.

For full-load current between unity and 75 per cent power-fac-

tor there is a difference of 1.6 per cent in the voltage-drop, the total drop being for the first case 2.7 per cent and for the second 4.3 per cent, quantities so large where the measurement of any considerable amount of power is concerned as to necessitate, for accurate results, that the transformer be compensated at the factory not only for its specified load but also at the power-factor at which that load operates. Otherwise the meters should be calibrated with the transformers to which they are connected.

A thorough investigation of the extent of the phase displacement of secondary voltage in pressure and current transformers has been undertaken by the National Bureau of Standards, the report on which may be found in abstract in the *Electrical World* of July 29, 1909. It will be published entire in one of the *Bulletins* issued by the Bureau. In the only report as yet printed no figures are given, but the statement is made that. "the shunt transformer is a device of high precision and that the same is true of the current transformer, but to a less degree."

It was originally the purpose of this investigation to develop a method devised by H. J. Ryan for the measurement of such phase displacement, and also of the effect of wave distortion, with the apparatus available in the ordinary laboratory or central station; but after a large amount of experimental work had been performed, instrumental errors were discovered which nullified the results. We hope, however, to give this method another trial.

Three-wire, two-phase connections. Turning now from the meter-transformer to the subject of polyphase connections, we will take up the question of distributing two-phase power over three wires. This connection was investigated because it is largely used in the distribution of power, and the belief has been expressed that the throwing of quarter-phased currents together into a common conductor will cause voltage unbalancing and phase distortion. This opinion is expressed in a recent and popular laboratory text book, in which a diagram is given to show that such effects are produced. Like so many diagrams of this nature, however, in order to show anything at all the proportions are so greatly distorted that the figure fails to represent practical conditions.

In Fig. 5*a* is given a diagram, the proportions of which are likewise distorted, which, it is believed, takes account of all of the factors in the three distributing wires that affect the voltage as delivered to the receiver.

T_1 and T_2 are the quadrature source electromotive forces.

Φ_1 and Φ_2 are the receiver electromotive forces.

r_1, r_s, and r_2 are the resistances of lines a, b and c, respectively, and are all assumed to be equal.

x_1 is the reactance of line a with respect to circuit $a\ b$.

x_s, is the reactance of line b.

x_2 is the reactance of line c with respect to circuit $b\ c$.

i_1, i_s, and i_2 are the currents in a, b, and c respectively.

There is also a transformer electromotive force in circuit, $a\ b$, induced by current in line c, and a similar electromotive force in circuit $b\ c$, induced by current in a, but it is doubtful if these are ever of appreciable value, so they have been omitted from an already crowded diagram.

The impedance drop in the middle wire, $i_s z_s$. Fig. 5a does

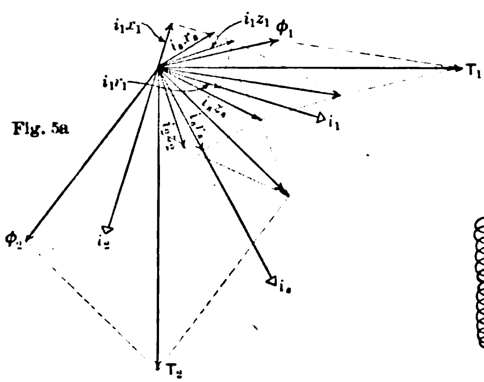

Fig. 5a

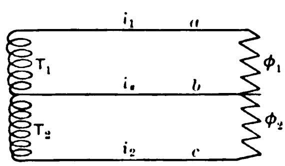

Fig. 5b

not combine symmetrically with T_1 and T_2 in producing the receiver electromotive forces Φ_1 and Φ_2. It is this fact which causes the increase in phase-angle between the receiver pressures and the difference in their values.

In drawing conclusions from this diagram it must be borne in mind: first, that the resistance and reactance of the individual leads are magnified out of all proportion; secondly, that the currents are assumed to remain equal and in quadrature. In an actual case, particularly if the load consist of induction motors, the last condition will not hold true, because as soon as any unbalancing of voltage or phase occurs, unequal currents with different power-factors are drawn, which check to a large extent the tendency to unbalance.

Two 4-kw. 2200/220- or 110-volt transformers were connected

to a receiver through a line 95 ft. long, consisting of three wires spaced 6.5 in. apart, the outer wire being No. 12 B. & S. and the middle of the same wire doubled for 41 per cent of the distance to give the same drop as either of the outer wires.

Resistance of each outer wire = 0.148 ohms.
Resistance of middle wire = 0.117 "
Reactance of each wire = 0.01 " (about).

The line gave, with full load on the transformers at 110 volts, about 12 per cent drop, and about 6 per cent drop with full load at 220 volts.

The results of a run on non-inductive load are given in Table I.

TABLE I

	Volts		Amperes		Angle phase difference	Per cent unbalance
	Phase A	Phase B	Phase A	Phase B		
No load....	110.4	110.5	0.	0	90° 48′	.09
Load.......	97.4	96.1	34.15	34 05	94° 57′	1.34

These figures, showing an unbalance of 1.25 per cent and phase distortion of 4° 9′, are of interest to the extent that they support the theoretical conclusion that there should be unbalance and phase distortion as a result of this connection.

When furnishing power to an induction motor at 220 volts the figures were, Table II.

TABLE II

	Volts		Amperes		Angle phase difference	Per cent unbalance
	Phase A	Phase B	Phase A	Phase B		
No load....	220.8	220.1			89° 46′	0.3
Load.......	195.2	198.0	18.23	19.8	92° 4′	1.414

Here there was an unbalancing of only 1.11 per cent and a shift in phase of 2° 18′.

In a diagram similar to Fig. 5*a*, which would attempt to show all of the electromotive forces in their relative proportions for our particular line, the vectors representing the line losses would be of almost microscopic size. This leads to the conclusion borne out by our experimental results, that for any case likely to be met with in practice the unbalancing or phase distortion will not be serious.

The same reason that led us to investigate the subject of

three-wire, two-phase distribution, also prompted the experiments on the open delta and Scott T, to determine to what extent these unsymmetrical connections may lead to unbalancing or phase distortion.

Open Delta. Fig. 6 shows two transformers connected in V on a three-phase circuit with a three phase, delta connected, non-inductive, load.

The currents in branches a', b', and c' are in phase with the electromotive forces in their respective branches. Current in transformer $c\,a$ is the vector sum of currents in a' and c'. Similarly, current in $c\,b$ is the vector sum of currents in c' and b'.

In Fig. 7 are shown the vector relations of electromotive forces and currents in the load circuit.

Electromotive forces a' and b' are also the transformer electro-

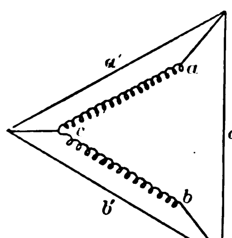

Fig. 6

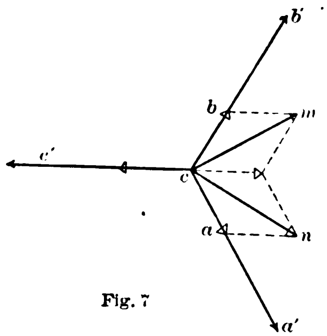

Fig. 7

motive forces $c\,a$ and $c\,b$, respectively. See Fig. 6. The sum of currents in c' and a' is $c\,n$ and the sum of currents in c' and b' is $c\,m$.

An inspection of this Fig. shows that in transformer $c\,b$ the current is lagging by 30° and in transformer $c\,a$ it is leading by the same amount. That is, each transformer, on non-inductive load, operates at 86.6 per cent power-factor. The result of this can be readily seen by referring back to Figs. 1 and 3. The effect of leading current in transformer $c\,a$ is to hold up the secondary voltage and shift it in phase behind its phase position on no load. In transformer $e\,b$ the lagging current causes a greater drop in voltage, but shifts the phase less than in the other.

In Fig. 8 the triangle $c\,a\,b$ represents the balanced electromotive forces of Fig. 6. Triangle $c\,a'\,b'$ shows the electromotive forces on non-inductive load.

The effect of drawing load has been to destroy the equality of voltages and to change the angle between the two transformer electromotive forces.

It should be borne in mind that the angle between the transformer pressures *a c*, *b c* and *a′ c b′ c*, Fig. 8, is actually the exterior angle *c*, or 180 degrees minus the angle here given. Thus, the actual effect of the delta connection is slightly to increase the angle between the two electromotive forces. For convenience in graphical representation the supplementary angle has here been treated.

In table III are shown the results of loading two 10-kw. transformers in this manner.

TABLE III

	Electromotive force			Per cent unbalance	Angle 'C' Fig. 8
	Phase 1	Phase 2	Phase 3		
No load	254.4	253.2	253.4	0.472	59° 58′
Load	246.6	240.3	236.6	4.05	58° 13′

Balanced non-inductive load, 50 amperes per phase. Phase 3 is the open phase.

With these particular transformers carrying approximately full-load current, there was an unbalancing of 3.58 per cent and a change of 1° 45′ in the phase-angle between their pressures. A convincing demonstration of the fact that the current in one transformer is leading was obtained by inserting a choke-coil in series, which caused an immediate increase in wattmeter reading, the current and voltage remaining practically the same.

The regulation on non-inductive load is chiefly of theoretical interest. The induction motor when operated from such a system exerts its customary regulating effect so that unbalancing and phase distortion are by no means so pronounced. Unfortunately, we had but one three-phase motor, which could load the transformers to only about half of their capacity so that regulating effects were not very marked. In Table IV are presented, however, comparative readings on non-inductive and induction motor loads of approximately equal value, which show relatively a greatly improved performance on inductive load over that on non-inductive load, although the unbalancing in either case was slight.

TABLE IV

	Electromotive force			Per cent un-balanced	Angle	
	Phase 1	Phase 2	Phase 3			
Non-inductive...	232.1	230.3	231.7	0.776	60° 12′	no load
Load........	229.2	224.4	223.9	2.31	59° 11′	load
Inductive	233.6	230.2	232.1	1.45	60° 3′	no load
load..........	226.0	224.3	222.5	1.55	59° 21′	load

Phase 3 is the open phase. The currents were 27.9 and 27.2 amperes per phase for the non-inductive and the inductive loads respectively.

For the non-inductive load the unbalance and phase distortion were 1.53 per cent and 1° 0′. For inductive load they were 0.1 per cent and 0° 42′ respectively.

The above results are of value only as a check upon the theory

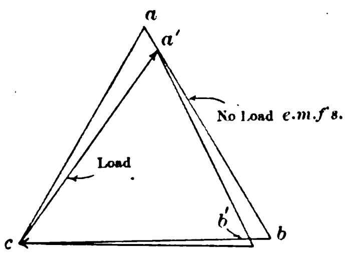

FIG. 8

that explains the regulation of V-connected transformers. In the most unfavorable case, when full-load current was drawn by a non-inductive receiving circuit, the unbalance was between three and four per cent. On inductive load the unbalancing would doubtless be considerably less, so that, judging from the performance of these two 10-kw. transformers, which are representative of modern apparatus, the unbalancing resulting from the V-connection or open delta is not likely to be serious, a conclusion doubtless in accord with practical experience.

When supplying induction motors with power-factors of from 85 per cent to 90 per cent, one transformer operates at about unity power-factor and the other operates at a power-factor of from 50 per cent to 55 per cent, lagging.

With initially unbalanced primary circuits, the transformer with the high voltage draws a heavier current, which, however,

if the power-factor of that circuit is the high one, will on that account exert a correspondingly less regulating effect; whereas the low power-factor current in the other transformer will exert a relatively greater effect, so that there may be no improvement in line conditions with load, a particular case in which induction motors fail to balance up the line. This is brought out in TableV.

TABLE V

	Electromotive forces			Currents			Per cent un-balance
	Phase 1	Phase 2	Phase 3	1	2	3	
No load.............	230.1	216.8	223.8	0	0	0	5.8
Load................	225.0	212.2	218.6	24.0	19.4	26.15	5.7

Referring to Fig. 6, phase 3 is the open phase *a-b*. Currents 1 and 2 are currents in transformers *a-c* and *b-c* respectively. Current 3 is the current in the lead wire from the junction point *C*.

Theoretically, then, the V-connection of transformers will cause unbalancing, due to the different power-factors at which the two operate; but with well designed apparatus supplying induction motors, this unbalancing should be small. With initially unbalanced circuits conditions may be such that the induction motors fail to exert any regulating effect.

These conclusions are based upon experiments in which the electromotive force was nearly sine wave in form. Where a pronounced third harmonic is present the pressure across the open side is much distorted, which might cause trouble aside from any phase distortion or unbalancing of the fundamental.

Scott T-connection. Fig. 9 gives the phase relation of current and electromotive forces in a system of two transformers T-connected, supplying power to a balanced, non-inductive load. *a b* represents one transformer and *c d* the other.

From this diagram it will be seen that currents of different phase relation flow in the two halves of the transformer which constitutes the top of the T. In one half, *a d*, the current is leading by 30 degrees and in the other half lagging by the same amount. This means, according to the curves in Fig. 1, that the regulation in the two halves will be different. Side *a c*

of the delta electromotive forces will tend to hold up its voltage and side $b\ c$ to drop off.

This is shown in Fig. 10, which represents to scale, no-load, half-load, and full-load voltage readings taken with the two 10-kw. transformers used in the tests on the open delta. The lines $a\ d'$ and $d'\ b$ show that the arithmetical sum of the voltages in the two halves of the transformer $a\ b$ is no longer equal to

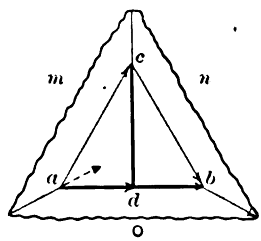

FIG. 9

the electromotive force between its terminals. The unbalance from no load to full load was 22.7 per cent.

These transformers are of the core type, with a primary and a secondary coil on each leg, wound for 2200 to 1100 to 220 or 110 volts.

In the run represented in Fig. 10 both primary and secondary coils were connected in series. That is, one-half of the secondary, represented by vector $a\ d$ Fig. 9, occupied one leg, and the

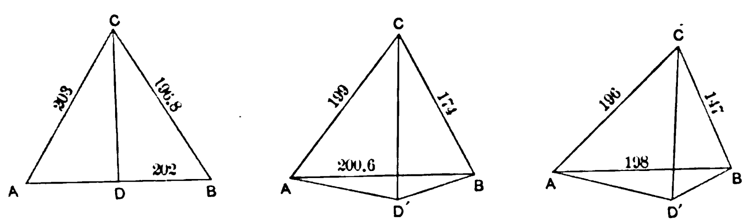

FIG. 10

second half $d\ b$ occupied the other leg. This is shown in Fig. 11.

The significance of this fact is as follows: in ordinary single-phase operation the ampere-turns between points x and y on the core are zero. That is, there is no magnetomotive force tending to establish leakage flux via the route $x\ y$. When, however, leading current flows in leg $a\ d$ and lagging current in leg $b\ d$ this is no longer true.

In single-phase operation the draught of load-current draws current from the primary whose ampere-turns neutralize the secondary load ampere-turns. In this case, however, with primary coils in series, but one load-current can flow, which can only neutralize the vector sum of the two secondary currents

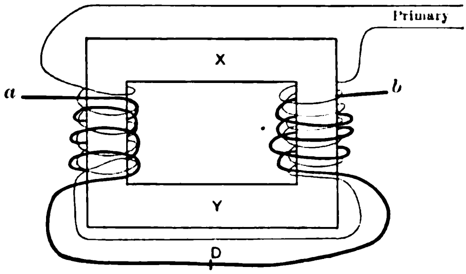

FIG. 11

This relation is shown in Fig. 12, which represents the primary and secondary currents reduced to a 1:1 ratio.

At the instant represented by point *o*, Fig. 12, the primary ampere-turns are zero, but in the two secondary coils the ampere-

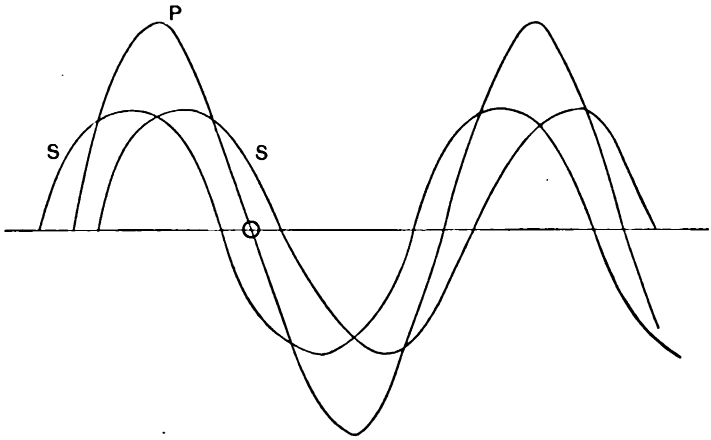

FIG. 12

turns are equal and opposite. This condition is represented in Fig. 13. At this instant the ampere-turns between *x* and *y* are 50 per cent of the maximum ampere-turns of either secondary coil. The result is an enormous leakage flux with consequent atrocious regulation. So great was the leakage flux with our

particular transformer that the case became hot, due to eddy-currents set up by the stray field.

With primaries in series as before, but secondaries in parallel, furnishing 110 volts, instead of 220, the regulation is greatly improved, as shown in Fig. 14, which represents no-load, half-load, and full-load voltage readings with the secondaries of both transformers in multiple.

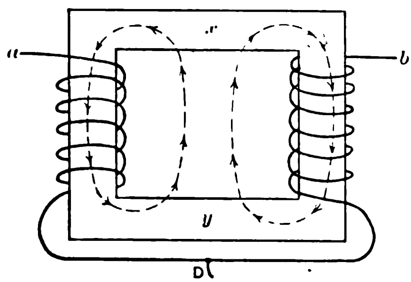

Fig. 13

The unbalancing from no load to full load is 2.3 per cent as against 22.7 per cent for the series connection.

When secondaries are connected in parallel the condition represented in Fig. 12 holds true for each leg of the transformer; but as the secondary winding on each core is split into two concentric coils, one completely covering the other, the ampere-

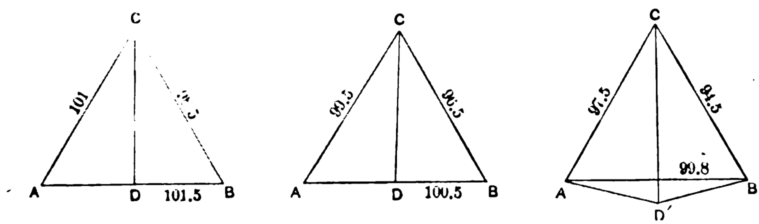

FIG. 14

turns of the two halves at the instant *o* neutralize each other, not only with regard to a path through the core but also with regard to the path *x y*, as shown in Fig. 15. For the sake of clearness the two halves of each secondary coil are shown separately.

The result is a greatly reduced leakage flux with consequent improvement in regulation.

By cross-connecting the secondaries, that is, by connecting terminals 1–3 and 2–4 together respectively, the condition shown in Fig. 15 could be realized for the series connection, with secondary voltage of 220, and good regulation would result, but the regulation with secondaries in parallel would then be poor.

As a further experiment, the two halves of the primary winding of transformer *a b*, Fig. 9, were each excited by means of separate transformers at 1100 volts, equivalent to placing the two primary coils in parallel across an 1100-volt circuit. With secondaries connected in series, the secondary current in one leg is leading and in the other lagging, but with each primary coil supplied independently of the other, it could draw a load current whose

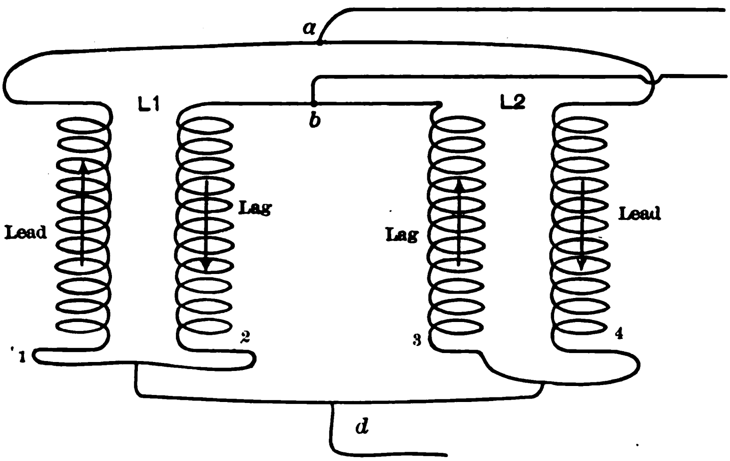

FIG. 15

ampere-turns would at all times equal those of its corresponding secondary, as in the single-phase transformer. The result was small leakage flux and good regulation.

TABLE VI

	Electromotive forces			Per cent unbalance	Average amperes per phase
	Phase 1	Phase 2	Phase 3		
No load.........	221.8	220	220	0.82	
Load............	200	194.6	192.0	4.0	38.9

With this connection the unbalance from no load to full load was only 3.2 per cent as against 22.7 per cent for both primaries

and secondaries in series. The currents were 41.9 and 47.1 amperes per phase for the parallel and series connection of primaries respectively.

As a final experiment three transformers were used, *a b* and *d b*, Fig. 9, each consisting of half of an independent transformer. This does away with complications due to leading and lagging currents in the same transformer and gives good regulation whether primaries are connected in series or in parallel.

Using three transformers, the unbalancing from no load to full load, secondaries in series, was 85 per cent. With secondaries in parallel the unbalancing was 63 per cent. These were for non-inductive loads. When operating induction motors the unbalancing was less, or even an improvement over no-load conditions; for, not having a tap on the transformer used as the stem of the T that was approximately 86.6 per cent of the base, the secondary voltages were initially unbalanced between one and two per cent.

Our tests were all based on transformation from two to three phases. When transforming from three to two phase, it is the primary of one transformer that carries different power-factor currents in its two coils, but the effect would be the same as with similar currents of equal ampere-turns in the secondary coils, so that any conclusions drawn from these experiments should apply equally well to both cases.

Wherever serious unbalancing is caused by T-connected transformers transforming from two to three phase, or the reverse, it is probably due to excessive leakage flux caused by different power-factor currents that circulate in the two halves of the transformer comprising the top of the T. This leakage flux may be greatly reduced and regulation correspondingly improved:

1. By proper interlacing of the transformer windings; secondaries if transformation is from two to three-phase; primaries if the reverse.

2. By joining in multiple the two halves of the transformer used as the top of the T, on the side that connects to one of the two-phase circuits.

3. By using three transformers, where available.

In conclusion, we wish to acknowledge our obligation to Professor Harris J. Ryan for the assistance which we received from him on numerous occasions during the conduct of these experiments.

Discussion on "The Electric System of the Great Northern Railway Company at Cascade Tunnel." New York, November 12, 1909

(*Subject to final revision for the Transactions.*)

President Stillwell: We are to have the pleasure this evening of listening to the presentation of a paper by Cary T. Hutchinson on "The Electric System of the Great Northern Railway Company at Cascade Tunnel." It is certainly a fact of great interest that in this year, 1909, a three-phase railway installation of magnitude has been completed and put in commercial operation in the United States. Polyphase motors were brought to this country in 1888. Those which arrived in that year were rated about one-quarter horse power, but none of them, I think, ever succeeded in developing that output. At that time serious efforts were made by American engineers associated with one of our manufacturing companies to adapt this type of motor to railway purposes, but they reached the conclusion that the constant-speed characteristic of the motor rendered it unsuitable for such service. A number of years later DeKando, in Europe, undertook to adapt polyphase motors to traction purposes, and it is a pleasure to have an opportunity to record the admiration that I feel, that I think all American engineers feel, for DeKando's exceptionally able and original work in that development.

The three-phase system has been in use in Italy, and in Switzerland, for a number of years, and, since 1904, on what may be called a large scale on the Valtellina line. From 1890 until recently but little attention was paid in the United States to the practical application of the polyphase motor to railway purposes. It received during that period, it is true, careful study; but the conclusions reached were negative, so it was not introduced in commercial service in this country.

In the United States there are to-day three different systems operating electric traction of the heaviest kind; namely, the direct-current system, the single-phase alternating-, and the three-phase alternating-current systems. All of these systems, I think it may fairly be said, are doing their work not only successfully, but in a manner that shows a marked improvement over the steam locomotive operation that they have superseded.

The steam railroad managements of the country are beginning to awaken. They are asking which is the best system for general railway work, and that question must be answered by the electrical engineer. A member of the committee of the American Railway Association said to me this morning that he felt the art was not sufficiently advanced to justify his railroad in considering seriously the application of electric motors. Now, the fact is that we have a variety of methods, and it is important to accelerate the process that ultimately is to result in the survival of the fittest.

It is here, I think, that one of the functions of this

Institute comes in. In this country there is no government commission to decide general standard specifications and to pass on the claims of various systems before adoption, as is done, for example, in Germany. With us, the evolution of a system is not directed, except so far as commercial interests may influence it, or the consensus of opinion of the members of this Institute affects it. I am always glad, therefore, to have this subject presented, because there is nothing within the scope of the American Institute of Electrical Engineers that is of greater technical interest, or that compares with it in commercial importance.

Cary T. Hutchinson: I shall not attempt to cover the entire scope of the paper, but shall merely emphasize a few of the features of the work. The first is that this system was installed with the expectation that it will form part of a larger system, having a length of from 60 to 100 miles. At present it is merely a shuttle service through a tunnel from a yard on one side to a yard on the other, the distance being about 4.5 miles.

If nothing further than this were contemplated, it would seem that such electrification would constitute a very serious additional expense, and this doubtless would be true, although owing to the peculiar conditions under which the steam service has been handled there is an actual saving in operating expenses over this stretch of about $100 a day. The fundamental reason, however, was increase in capacity. This tunnel formed the congested point of the railroad system; under some conditions it was almost impossible to get the tonnage through the tunnel.

A short description of the method of handling the traffic under steam will indicate the difficulties that were encountered. Trains east-bound from the Pacific coast were from 1400 to 1500 tons trailing load with two Mallet compound engines. At the west end of the tunnel, at the foot of the grade, all trains were stopped, fires were hauled and cleaned, the engines took on a special high-grade coal, new fires were built and the engines remained in the yard for an hour or more, coking these fires in order to get rid of superfluous gas. In addition, a helper engine was kept in the yard, which used the same grade of coal and with the same precautions. The train was divided into two parts, the helper engine taking about 400 tons through and the two Mallet engines afterwards taking the remainder of the train, say 1000 tons.

When weather conditions were bad it was almost impossible to get trains through the tunnel; sometimes it was necessary to wait two or three hours after the passage of one train before it was safe to send a second train through. Frequently the steam pressure in the rear Mallet engine would fall from 200 lb. to 70 lb. or less, owing to the impossibility of maintaining fires on account of the exhausted condition of the air in the tunnel. The train would then have to stop and be split into two sections, and it would be necessary to back the rear engine out with part of the train.

These conditions also had a very bad effect on the train crews. Good engineers would not stay on the division; it was considered dangerous service.

Under these conditions Mr. James J. Hill, finally determined, after several years' consideration, to try out an equipment at the tunnel with the express intention of using it on the entire mountain division, if it proved to be satisfactory. These were the conditions that led to the adoption of this particular system.

W. S. Murray: As a single-phase man in other fields I wish to say that as far as the Cascade Tunnel *per se* is concerned, I am heartily in agreement with Dr. Hutchinson's chosen method of electrification. It is my belief that the physical conditions call for this method. Assume any piece of trackage, either one mile or 300 miles in length, at constant grade, whether zero or such a percentage that admits of adhesion of the locomotive driving wheels, and with no stops in the schedule (or if inclusive of stops then with exceedingly low train acceleration). Under these conditions, particularly where single track is involved, thus eliminating any complication of overhead construction, it is my belief that the three-phase system would be correctly applied.

Dr. Hutchinson says that traction developed by motors of the three-phase type admits of 3 per cent or 4 per cent greater adhesion than in the case where single-phase motors are used. Now, the single-phase motor is admittedly heavier than the three-phase motor of the same capacity, and, therefore, if it lack adhesion in its torque developing characteristic—which statement is by no means accepted by all—the deficiency is taken care of by its excess weight, thus illustrating the old adage, "It is an ill wind that bloweth no man good."

Though the subject treats of a three-phase installation, I am sure that Dr. Hutchinson will not object to an effort at drawing the line between the application of three-phase and single-phase apparatus. Dr. Hutchinson speaks of the advantage of a frequency of 25-cycles. This frequency is also applicable to single-phase installations, but it is true that the use of three-phase apparatus assures less costly generators. This saving, however, is offset in the case of single-phase installations by less costly switchboards. It is interesting to note that it is not much more expensive to use three-phase generators for single-phase distribution, as the new type of dampened field cuts down the rising voltage on the idle phase, making it possible to develop and use three-phase current for commercial requirements.

Concerning the speed of trains propelled by three-phase or single-phase motors. Infrequently it is said that a train under three-phase propulsion is more certain of making its schedule, on account of its constant-speed characteristics. Now, there is no desire on the part of the single-phase motor not to go. If we should place impress 500 volts on the terminals of one of Dr. Hutchinson's three-phase motors, and on one of the New

Haven locomotive single-phase motors, subjecting neither to any load, the former, if a frequency of 25-cycles were used, would arrive at 300 revolutions and go no higher, while the single-phase motor would, in a very short interval of time, arrive at a speed far in excess of that of the three-phase motor. The speed of the single-phase motor depends simply on the balancing resistance of the train, at the voltage applied to the motor. If the required balancing speed is 60 miles an hour, there is a voltage that corresponds to this on the transformer; it is simply for the engineer to see that the controller is on the right notch to supply it. Speed is a direct function of voltage, and the single-phase motor receives its voltage without the interception of resistance. Resistance, both within and without the circuits of the motor, means loss. In the case of the three-phase motor, except cascade connection, resistance has to be inserted for all speeds below the normal slip-speed of the motor.

The true speed-torque traction curves for railway motors were given by the direct-current series motor long before the alternating-current motor, either of the induction or the single-phase type, put in an appearance. In general it may be said that this type of motor conserves the apparent necessity of a service having a motive power which, at high efficiency, will take care of variable-speed requirements made necessary by accelerations, slow-downs, and stops. Horse power is directly proportional to speed and torque. On a grade the series motor admits of a lower speed, which, taken with the increased torque requirements, tends to keep the horse power constant; in the case of the polyphase motor, the speed remaining constant with the increase of torque required, due to grade, the horse power rises. It is thus clear that the single-phase motor, with speed characteristics similar to those of the direct-current series motor, admits of maintaining nearly constant load upon it under varying conditions of grade: with the three-phase motor, the load, for the reasons stated, must vary over exceedingly wide limits. For example, Dr. Hutchinson's locomotive, when hauling a train up a 2.2 per cent grade, has to develop six or seven times as much power as when hauling the same train on a level. A constant load-factor cannot fail its appreciation, be it in a power house or an electric locomotive, and the illustration previously made is an attempt to bring out the just reason for Dr. Hutchinson's application of the three-phase motor to special conditions of constant grade, no stops or low acceleration, and that of the single-phase motor in the field which admits of great variation in grades and higher acceleration.

To exemplify more concretely the point made in the previous paragraph, Dr. Hutchinson says that the Cascade Tunnel electric locomotive requires only 20 per cent more power in accelerating a train in the tunnel grade than in running the same train on the same grade at full speed. This is interesting, and convincing as to the ability of an electric locomotive of this design to take care of the concrete conditions cited.

It is also interesting to analyze this conclusion. To accelerate a train on grade it is necessary to overcome three classes of resisting forces:

1. The inertia of mass.
2. The resistance of frictional parts.
3. The resistance of gravity.

At an acceleration at the rate of 0.1 of a mile per hour per second, the resisting force due to inertia of mass is 10 lb. per ton. The friction per ton in a freight train, inclusive of the locomotive, may be estimated at 8 lb. per ton, though this is high. The grade is stated to be 2.2 per cent. Gravity offers, therefore, at 20 lb. per ton, a total of 44 lb. Thus, the total resistance per ton to accelerating on the grade in question is 62 lb. After the train has been accelerated to speed, 10 lb. of this 62 lb. drops out, due to the disappearance of mass inertia. The ratio of 62 to 52 is practically 20 per cent, as Dr. Hutchinson points out. Under this analysis it is not difficult to see, however, why the ratio is so small. If we drop the acceleration to 0.05 of a mile per hour per second, then the difference would have been only 10 per cent. The two things that cause this ratio to be so small is the low acceleration and the high grade.

Exactly opposite conditions exist in high-speed suburban passenger service, where the acceleration is exceedingly high and grade is practically eliminated. As an example, under the conditions of no grade, a passenger train being accelerated at 0.7 of a mile per hour per second will require 70 lb. to the ton, and assuming the average friction per ton up to 60 miles an hour to be 10 lb., the total pounds per ton required is 80. After the train has arrived at the balancing speed of 60 miles per hour, mass inertia disappears; the remaining resistance, train friction, may be 15 lb. per ton. Now, it is seen that the ratio of the torque required to accelerate this train to the torque required to keep it at 60 miles an hour is 80 to 15, or the increase instead of being 20 per cent is 530 per cent. An acceleration of 0.7 mile per hour per second is not unduly high for a suburban service on trunk lines, and this analysis is an attempt to bring out the great difference between the case cited and the duty requirements of the Cascade Tunnel locomotives.

I agree with Dr. Hutchinson that in regard to mechanical clearance, ⅛ in. is ample for all practical purposes. The method suggested for dividing up the load uniformly on the motors by the insertion of resistance would seem to be practical. As these resistances must be continually in series it would be interesting to know what percentage of loss is incurred; doubtless it is low.

The single-phase system, such as, for example, that of the New York, New Haven & Hartford Railroad Company cannot claim any higher power-factor than that mentioned by Dr. Hutchinson in the case of the Cascade electrification. Power-factor in a system is an interesting detail. It is possible to be misleading. The New Haven road is a large user of single-

phase power, and its power-factor seldom rises above 85 per cent. Indeed, it is more frequently below 80 per cent. It is well to know, however, exactly what power-factor stands for. A high-voltage system primarily stands for very low transmission losses. Let us assume, for example, that the actual transmission losses of the New Haven systems are between 5 and 10 per cent at unity power-factor. Even should the power-factor sink as low as 75 per cent, this would mean that the line loss, instead of being from 5 to 10 per cent, would be from 6.7 to 13.3 per cent. Remembering that many systems have a normal loss of 25 per cent, it would seem that the fluctuation of power-factor, even within wide limits, is not serious.

I am in agreement with Dr. Hutchinson that the yard proposition on two overhead wires is not practicable, and I also believe that this is true of main-line tracks where high speeds and many switches are involved. I wish to support Dr. Hutchinson's views in regard to simplicity, capacity, and reliability of the induction motor. I have always had the greatest respect for this kind of motor. It is my great regret that its electrical characteristics do not, in my belief, conform to those required by the general traction problem. It is to the alternating-current series motor what the direct-current shunt motor is to the direct-current series motor. The direct-current shunt motor has disappeared forever on all traction lines, and I do not believe that it can reappear under the cloak of alternating current.

E. B. Katte: Sometime ago I had the privilege of seeing one of the electric locomotives in the works of the manufacturing company and believe it will be hard to improve upon either the electrical or mechanical design for the speeds for which the engines are intended.

The reasons for adopting a three-phase system over the whole mountain division are quite obvious, but I am surprised to note that this same system would probably have been used if only a four-mile tunnel section was to have been considered. Without going into figures, it would seem that a direct-current system with storage batteries would have made unnecessary the use of steam locomotives in starting electric trains, and at the same time would have relieved the power station from the sudden inrush of current, thus securing better regulation at the water wheels. And further, by adopting multiple-unit control for the locomotives, two or more at the head end of a train could have been operated with one-half the number of men.

Dr. Hutchinson describes the ground-wire, provision for which has been made on the top of the transmission-line poles, but states that it has not yet been installed. I wish he would explain why the ground-wire was finally omitted. When the transmission line of the New York Central was designed, similar provision was made for a ground-wire, but after further consideration it was left out; for the reason that the poles were of

steel and each carefully grounded to a large copper place set in permanently wet ground, and it was believed that each pole would act as a lightning rod and thus protect the line. However, on the Great Northern line the poles are wooden and the insulator pins do not seem to have been grounded, consequently if a ground-wire is ever necessary, these would appear to be conditions under which it would be most valuable.

The fact that wooden poles are used through forests leads me to ask if any special protection against destruction by fire was adopted. Last year when estimates were made for the information of the "up-state" Public Service Commission, covering the cost of electrifying railroads through the state forest lands, it was considered necessary to use steel poles because of the danger due to forest fires.

The experience with insulators covered with soot from steam locomotives is similar to that on the New York Central system. At first we were much perturbed because of the soot which was accumulated upon the 11,000-volt insulators in yards used by steam locomotives through which the transmission line passed, but after careful tests on several insulators which were well covered with soot it was found that the flashing-over point was several times the normal voltage even when the soot was well saturated with water.

Among the minor advantages to be derived from electric traction, brought out in this paper, is the possibility of knowing at any instant, by the direct reading of meters, the exact operating condition of any element of the system. I believe this to be more than a minor advantage and think it of very great importance and help to those charged with the safe and reliable operation of trains.

Bion J. Arnold. During the last summer I rode through the Cascade tunnel several times on the electric locomotives described by Dr. Hutchinson. I was interested in the operation of the system. It seemed to perform its work as satisfactorily as any direct-current or single-phase installation I have ever seen. It had the objectionable double overhead conductor, and the yard was necessarily somewhat complicated on that account. I agree with Mr. Murray that for a railroad with many yards—and many yards are the rule with steam railroads if an overhead conductor is to be used—the single-phase installation is preferable. That is one of the principal reasons why the single-phase system was used for the tunnel of the Grand Trunk Railway system between Detroit, Michigan, and Sarnia, Ontario—a tunnel installation similar to this, terminating at each end in a vast yard with a number of tracks, and located in a climate where snow and ice were likely to cover tracks—over which the train movements were infrequent. I concluded that under such conditions a third-rail might become iced or covered with snow, making it difficult at times to move trains. These and other conditions impelled me to adopt the single-phase system,

and at a time when such a system had not been tried on heavy traction work. The Grand Trunk installation has been in successful operation for some years, and so far as I know there is no desire to adopt any other system.

We all know that both the direct-current system on the New York Central and the single-phase system on the New York, New Haven and Hartford are operating successfully. Mr. Sprague and others are advocating a high-potential, direct-current system, and I have no doubt that within moderate limits that system will be equally successful. All of this tends to show that while we may individually believe in some particular system, none of us can prove conclusively that his is the ideal system—and that when conditions arise which call for the development of a new system, such a system will be properly developed and applied.

I am surprised at the excessive friction of the Mallet compound locomotives. Dr. Hutchinson gives it as an average of 46 lb. per ton. Ordinarily the friction load for steam railway trains is estimated at 6 lb. per ton on level straight track. This excessive friction is probably due to the greater number of cylinders, reciprocating parts, and extra weight of the valve motion of these engines; and it indicates that some of the advantages of these immense engines are offset largely by this excessive friction, especially when they become a trailing load. What is the friction of these engines when running under steam? I assume that this table gives the friction when the engines are being pulled as trailers by the electric locomotive.

Dr. Hutchinson says he adopted a method which gave him a single speed, for his electric locomotives and that resistance was used when starting. He also says that one of the reasons for doing this was to obtain simplicity, giving as an additional reason that the power cost was nothing, being developed by water power, consequently he could afford to waste it in starting the locomotives. But such practice would not do in case the power were produced by a steam power plant on a railroad of any great magnitude. I think, therefore, that a different conclusion would have to be drawn as to the method of control to be adopted, in case the three-phase system were made applicable to a large railway system. In this respect Mr. Murray has pointed out the superiority of the single-phase system, as far as economy of operation and securing of variable speed is concerned.

F. N. Waterman: As one who has advocated the consideration of three-phase motors for railway work, I am particularly gratified by the evidence of its advantageous application as set forth in the paper of the evening. There is one interesting property of induction motors which is not exhibited in the present instance, because only one train is operated; namely, the action of moving trains as fly-wheels to keep down the peaks or to minimize the fluctuations of output of the central station. This

was illustrated by the operation of one of the electrified divisions of the Italian state railways, known as the Valtellina line. The traffic comprised freight and passenger service, with an average of from four to six trains running simultaneously. With only one train running, as occurred at the extremes of the day, the ratio of maximum to average ordinate of the output curve was about 3.5 to 1. The average run was short, requiring frequent accele ation. With a number of trains on the line, the ratio of maximum to average output fell to 1.7 or 1.8 to 1, giving a load-factor of 55 to 60 per cent. The reason why the ratio of maximum to average was as favorable as 3.5 to 1 with single train operation, was the employment of the cascade control for most of the trains. The freight was handled at that time, in the manner adopted by Dr. Hutchinson, by rheostatic control with a low rate of acceleration. The remarkably favorable results on the Italian state railways was unquestionably due to the peculiarity of induction motors, that they cease taking current if the frequency falls by the amount of their slip, and return current if it falls to a greater extent. The water wheels driving these generators fell off in speed some five per cent, as full load came on, while the average slip of synchronously running trains was less than one per cent. Hence, as the shock of starting a train came upon the power house, the frequency fell, and it had to fall only one per cent entirely to relieve the station of other loads. A further fall would cause the moving trains to return energy to the line and help supply the starting current. This momentary relief of the station resulted in the high load-factor noted. It would appear that this property of induction motors should be of great value where a small number of trains is operated.

Of course, relief of the power house by this means is only momentary. Whether it would be of consequence at all in such a proposition as Dr. Hutchinson is dealing with is perhaps problematical. The starting of a 1600-ton freight train is a very different matter from the acceleration of a 125- or 150-ton passenger train, and the time-interval during which the fly-wheel action is effective might very readily be so small that the advantage would not be realized to anything like the same extent, but it is a property resulting from the constant speed characteristic of the motor, which in many cases is of large consequence, and in any case is extremely interesting, as being not merely a theoretical deduction, but as proved out in the practice of the Italian State Railways. The tandem control, which has been spoken of as " messy ", is employed by the Italian state railway, even on a recent installation, which is like this Cascade installation in being a through haul on a constant grade.

I had some calculations made a short time ago showing the effects of tandem control of three-phase motors in comparison with the series-parallel control of the New York Central locomotives. It was impossible to include a computation for the

single-phase locomotive, because sufficiently accurate information regarding the performance of single-phase locomotives was not available. Table I shows that the tandem control with two speeds—a method that leaves the entire equipment available for either kind of running—is at least not inferior to the New York Central locomotives, employing four motors and their three groupings, in respect of maximum draught on power house or total energy consumption, but is rather better. If handled on the basis of constant-current input, which is not the custom in direct-current practice in this country, I believe the three-phase locomotive will show rather a noticeable advantage when the application of the three-phase motor to railroad work has received the same thorough study and development as given to the direct current motor. If experience abroad may be taken as a criterion it will be found superior for many purposes, to any other form of motor.

COMPARISON OF THREE-PHASE AND DIRECT CURRENT LOCOMOTIVES.

Type of locomotive	Total train weight tons	Net train weight tons	Distance in feet	Time in sec.	Speed maximum miles per hour	Kilowatt maximum	Kilowatt hours	Watt-hours per ton-mile gross	Watt-hours per ton-mile useful
New York Central (weight 95 tons)..	435	340	27300	426	58.4	1920	110	49.4	62.8
Valtellina 2 speed type (weight 68 tons)	408	340	27300	426	58.5	1660	104	49.1	59.4
Valtellina 3 speed type (weight 68 tons)	408	340	27300	425	58.5	1660	91.5	43.5	52.3
New York Central..	265	170	29800	403	60.5	1800	82	54.9	85.5
Valtellina two-speed type............	238	170	29800	404	59.5	1660	71	52.8	74
Valtellina three speed type.............	238	170	29800	402	59.5	1660	60	44.7	62.5

Notwithstanding the use of cascade control on the Valtellina locomotives, the control apparatus is much more free from complicated or messy apparatus than that of any electric locomotive in use here. This results from the use of liquid rheostats with compressed-air control. A limit relay is used to maintain the rotor current constant, and the rate of acceleration is determined merely by the notch in which the handle of the controller is set. In the simplicity and small space requirements of the control apparatus there is a great contrast in the appearance of these Valtellina three-phase locomotives and that of the large locomotives in use in this country.

From a mechanical point of view I was much interested in the motors of the Italian state railways. The clearance used there between rotor and stator is 2 mm., about

$\frac{1}{12}$ in., and the wear of the bearings, in some 60,000 miles of operation on these locomotive motors, was about 0.3 mm. The reason for such a result is that the collector rings are outside the bearings, leaving it only necessary properly to proportion the spiders to have virtually the entire interior of the rotor for bearings and lubricating means. While the three-phase motor, particularly if arranged for cascade operation, requires an air-gap as small as $\frac{1}{12}$ in. the remedy is present in ample bearing space. Dr. Hutchinson points out some of the advantages of the three-phase motor; the foregoing seem to me to be further advantages.

J. H. Davis: The system described marks an epoch in the history of heavy railroad electrification in the United States. It is the first attempt in this country to use the three-phase induction motor for handling heavy passenger and freight trains on a trunk line railroad.

I am especially impressed with the importance of the electrical engineer's decision in recommending the adoption of a certain system of electrification. His decision is second in importance only to that of the engineer locating the railroad. A decision to use this or that system of electrification for a certain purpose, as, for instance, handling heavy traffic over a mountain division, will, of necessity, have great weight in determining the system of electrification to be used when other divisions of the road are electrified. The system thus adopted may or may not be that which is best suited for the desired extension. If the entire road is eventually electrified, one system of electrification should be used throughout, although this system may not be best adapted to all of the various conditions to be met. Therefore the system adopted should be that which is best adapted to the requirements of the road as a whole. The necessity for interchange of equipment from one division to another is well known, and in meeting this requirement the electrical engineer can best obtain simplicity of equipment by confining himself to one system of electrification. The gain in this direction will be more than sufficient to offset the loss due to the adopted system not meeting in the best way some of the conditions.

Inasmuch as the conditions at Cascade Tunnel are very similar to those encountered on the Belt Line Railroad of the Baltimore & Ohio, where direct-current electric traction has been used for 14 years—this being the first installation of electric locomotives for heavy traction purposes in the United States—a comparison of the physical conditions, train weights, tonnage handled, equipment used, etc., may be of interest. This comparison I give in the subjoined Table I.

It might be added that the working conductor on the electrified section of the Baltimore & Ohio was originally placed overhead, its design, however, being very different from that used at the Cascade tunnel. The low working voltage on the Baltimore & Ohio necessitated the collection of a large amount of current, and a rather complicated overhead construction was

necessary. Serious trouble was experienced in maintaining this overhead structure, and for this reason it was abandoned and the third-rail installed.

TABLE I.

Physical conditions:	B. & O. R.R.	G. N. Ry.
Length of electrified section	3.7 miles	4.0 miles
Ruling grade	1.5%	2.2%
Average grade	1.0%	1.7%
Length of longest tunnel	7,400 ft.	13,873 ft.
Train weights:		
Freight, including steam and electric locomotives	1928	2075
Passenger " " " " "	990	906

Tonnage handled per day:	B. & O. R.R. No. of train	B. & O. R.R. weight	G. N. Railway No. of train	G. N. Railway weight
Passenger	21	6,630	3	2,690
Freight	28	29,600	2.5	5,290
Special	0		1	470
Totals	49	36,230	6½	8,350

Equipment:	B. & O. R.R. Pass.	B. & O. R.R. Freight	G. N. Ry. Freight
Number of locomotives	5	2.5	4
Weight, tons	90	160 (2 units)	115
Number of motors	4	8	4
Rated horse power	1,100	1,600	1,900
Tractive effect, rated load	26,000	70,000	47 600
Speed at rated load, miles per hour	16	8.5	15

NOTE:—Data on B. & O. equipment based on natural ventilation: Great Northern on forced ventilation.

L. R. Pomeroy: About seven years ago I made an examination of the Cascade Tunnel to determine the possibilities of electrification. At that time it was very difficult to arrive at the actual cost of steam operation, on account of the fact that the motive power statistics furnished were for average and general conditions complicated by the addition of constructive switching and arbitrary mileage.

Since then I have been furnished with a road test of a Mallet locomotive over the section described in the paper, namely from Leavenworth to the Cascade Tunnel summit, a distance of 32.4 miles, with an average grade of 1.35 per cent and a limiting grade of 2.2 per cent. Also from a neighboring road, having similar physical conditions, an actual coal record; that is, tons of coal used for a period of six months, of individual classes of locomotives, representing 156 locomotives making 1,382,092 miles, and consuming 174,121 tons of coal, as follows:

No.	Class	Engine-miles	Tons of coal	Pounds per 1000 ton-miles	Pounds per engine-mile
55	2-8-2 simple.	291,070	33,418	191	230
6	2-8-2 compound.	81,150	10,275	175	251
24	2-8-0 simple.	299,036	33,931	345	227
71	2-8-0 compound.	710,836	96,479	306	271
156		1,382,092	174,121		

Some figures of the test referred to are as follows:

Distance	32.4 miles.
Running time	4 hr. 0 min.
Time lost in stops	3 " 4 "
Total time	7 " 4 "
Average speed (miles per hour)	8.1 miles.
Pounds of coal used per trip	23,100 lb.
" " " " " square foot of grate, per hour	74.03 "
" " " " " mile	717 "
" " " " " 1000 ton-miles	896 "
Average tonnage hauled	810
Average number of cars per train (all loaded)	21
Average grade	1.35%
Maximum or ruling grade	2.2 %
Indicated tractive force	60 000 lb.
Type of locomotive 2-6-6-2 (L2)	Mallet
Total weight of locomotive	225 tons.

From the foregoing data the writer desires to present a few deductions.

A train with a trailing load of 2500 tons over the section of road on which the test was made will require about 5750 kw-hr. at the rail per trip.

Assuming a modern steam generating station, the coal used per trip at 15 miles per hour would be about 5 lb. per kw-hr. (at the rail) or a total of 28,750 lb. With the same tonnage per train under steam conditions at 15 miles per hour, three steam locomotives would be necessary.

Increasing the speed of the steam train from 8.1 miles per hr. to 15 miles per hr., reduces the tonnage about 30 per cent per locomotive. 810 tons trailing load plus 225 tons, the weight of the locomotive, times 70 per cent, equals 725 tons per locomotive. The coal consumption of the steam train then becomes 32 miles times 717 lb. per mile times three locomotives, equals 68,832 lb. Percentage of difference in favor of electricity:

$$1 - \frac{28,750}{68\,832} = 58 \text{ per cent.}$$

Going back to the coal used by the 156 steam locomotives—these locomotives are used on two mountain divisions—for six months; namely, 174,121 tons. For a year the amount would equal 348,242 tons. At the rate of $2.00 per ton for Crow's Nest coal, the cost of coal equals $696,484. Also the cost for water used would be about $25,000. It has been shown that the coal saving amounts to 58 per cent. Calling this one half or 50 per cent, the saving would equal $348,242. It is claimed that the Mallet type of locomotive is 30 per cent better than the types composing the 156 locomotives referred to. We will, therefore, reduce this amount to correspond. $348,242 times 70 per cent equals $243,769; add the saving in water, $25,000, and the net saving then becomes $268,769. This amount capitalized at 5 per cent represents $5,375,380. This amount alone, not

figuring on other savings, such as train crews, reduction in train-mileage with the same tonnage, and the advantage of a great increase in capacity, would go to show that such a mountain section comes very near being a situation where we can accomplish by electrification what is now impossible under steam conditions.

In the table of test data it will be seen that the time to make the run was 7 hr. and 4 min.; time consumed in stops or laying in side tracks, 3 hr. and 4 min.; time in motion, performing useful work, 4 hr.

Approximate figures from four railroads which give separately in the annual reports the coal per locomotive-mile for freight and passenger service, based on the total coal charged to engines for the year, the consumption per horse-power-hour is as follows:

	Passenger	Passenger and Freight	Freight
Road A	12.30		9.64
" B	12.86		11.20
" C	14.00		10.00
" D		10.63	

while from individual road tests we find the coal consumption frequently is from 4 to 8 lb. per horse-power-hour.

The point that I desire to make is that it is not quite fair to the electric side to base the comparative costs on a road test without adding a liberal amount to cover this "contingent" feature.

In Tables III and IV the resistance of the Mallet locomotives is shown to be in the neighborhood of 50 lb. per ton exclusive of the resistance due to gravity. This is not to be wondered at when the sizes of the pistons are taken into consideration. The L-1 locomotive has cylinders 21.5 in. and 33 in. by 32 in. stroke and the combined area of the four pistons is 2436 sq. in. If atmospheric pressure of 15 lb. per square inch is figured against the low-pressure pistons only, the thrust equals 25,659 lb. A large share of this piston resistance is by-passed, but the fact that these locomotives cannot drift freely down a hill without a slight opening of the throttle, and from the tests shown in the paper, it would seem that the by-pass valves should be supplemented by some form of drifting valve which would result in materially reducing the resistance found in towing the locomotive with closed throttle. It is customary with some railroads to base the value of saving due to elimination of curves and grade reduction, not on the increased capacity, but on the money value of a reduction in train-miles. For example, on a division of 225 miles having seven freight trains per day the value of each one per cent in reduction of train-miles is about $3000 per annum, the capitalized value of this amount at 5 per cent per annum equals $60,000 for each one per cent of saving. The rate

per train-mile being 50 cents, which represents the costs directly affected; that is, transportation expense not general expenses. This being the case, figures representing costs of electric service on this basis will directly appeal to railroad managers; whereas figures based on increased capacity are more or less problematical and open to doubt.

W. N. Smith: Although for a dozen years or more the three-phase system has been firmly established as the standard for general power transmission, certain disadvantages incident to its use have until now deterred engineers in this country from undertaking to avail themselves of some of its inherent advantages in heavy electric traction. It has been reserved for the author of the paper to be the first in the United States to reduce theory to practice and to place before us a general description of the construction and performance of a type of electric locomotive which, so far as this country is concerned, has never before emerged from text books and technical papers.

It seems to me that in the case here treated, operating conditions are such that the advantages of the three-phase system are of maximum importance, and the disadvantages of minimum importance. The relative advantages are clearly stated by the author and need no further comment. On the other hand, the chief disadvantages of the three-phase system, reduced to their lowest terms, are the harnessing of the inherently constant-speed motor to variable-speed duty, and the necessity of two trolley wires instead of one.

The first objection is largely minimized in this electrification by the nature of the train service and the character of the railroad line itself, both of which favor maintaining a constant speed. Whether or not there is any valid objection to maintaining a constant speed on a long railway line on the surface, there can certainly be none to doing so in a tunnel; and the speed is so moderate that the relatively inefficient performance during acceleration is not of long duration in proportion to the entire length of the run. In this case the acceleration seems to last about 1.5 min. out of the 12 to 14 min. that would be required to make the tunnel run.

The objection to two trolley wires is partly obviated in this case by the slow speed of 15 miles per hr. In my opinion this is the salvation of the wheel-trolley contact system here adopted. But even slow speed cannot mitigate all the disadvantages of two trolley wires of opposite polarity.

I have somehow received the impression that our European friends operate their railroads under some conditions that seem inapplicable to our roads. They appear to have a somewhat different view-point, to which both the employes and the public are accustomed: they pay strict attention to methodical detail all down the line, and subordinate the results thereto; while in this country the aim is more toward the final result and all possible time-consuming details are regarded as secondary to

that result. This is the only way I can account for the favor with which the Europeans apparently regard the use of two trolley wires. They seem to have tackled this phase of the problem with remarkable freedom from the prejudice against it that has always existed in this country.

In a long straight tunnel taken by itself the double-trolley construction adopted by the author does not seem to present any unusual difficulties in maintenance. It seems to have been experienced in long-tunnel electrifications that the transition period from steam to electric power is the time when insulation is most likely to fail. The worst difficulty with the double-trolley wire seems to me to be at track intersections where moving contact must be made at will, upon intersecting wires of opposite polarity, without risk of short-circuit, and without danger of temporarily checking headway and injuring draft-gear by losing power for a few seconds when accelerating a heavy train at slow speed. The first of these considerations is all-important. The second depends on how many chances it is safe to take by temporarily cutting off or reducing the locomotive torque while starting a heavy train. Under the conditions of the Cascade Tunnel electrification, with main and side tracks at tunnel portals on a two per cent grade, it would seem necessary to have two sets of trolleys in contact, one set at each end of the locomotive when passing switches, at least whenever conditions make steady acceleration difficult, as with snow on the rails and journals stiffened by frost, and excessive train weight.

The paper betrays some dissatisfaction on the part of the author as to results so far accomplished with the double-trolley system as here developed. In working out improvements he will have the sympathy and encouragement of all who realize that, after all, the mechanical reliability of the moving contact system is the very foundation of successful electric railway operation, regardless of the kind of current employed. It is this feature that appeals to me as being susceptible of the greatest improvement. It is in respect to the trolley problem that the single-phase system is likely to be regarded as superior for some time to come.

It seems to me that future development in the perfection of the moving contact will be in the way of the wide roller type with pantagraph mounting, as distinct from the narrow trolley wheel or the sliding shoe; for the sliding shoe, widely used for high-speed work at the present time, seems susceptible of further betterments, if wear and tear at high speeds and heavy currents are to be overcome.

It is quite conceivable that ultimate speeds of 20 to 30 miles per hour may sometimes be thought advisable for some classes of train service on a mountain-grade line of this type instead of the 15-mile speed chosen for the heavy freight service of this installation. This refers more particularly to fast passenger and light freight trains. Train-speeds that operating economy

may demand in the future ought not to be rendered impossible by the limited reliability of the time honored trolley wheel for high speed in such heavy service, particularly when passing switches.

The same considerations of speed prompt the opinion that the next locomotives to be built for this electrified section, or a similar one, will be fitted either with pony wheels or with side-rods for coupling to motors placed on top of the frames, or possibly with both of these contrivances. There seems to be no mistaking the tendency that has set in during the last two or three years, for electric locomotive construction to be guided more and more by the experience gathered during the two generations of steam locomotive practice. The boasted simplicity of the geared or gearless motor hung directly on the locomotive axle has proved disadvantageous in some other respects. The increased flexibility of locomotive design from the mechanical standpoint, which is consequent upon placing the motor on top of the frame and using side-rods and jack-shafts, and the general mechanical uniformity with the frames and running gear of existing steam locomotives, will make an electric locomotive appear more like a standard piece of machinery to the railroad operating man than has hitherto been the case. The great advantages will be the raising of the center of gravity, the ready standardizing of mechanical parts independently of electrical equipment, and the ability to use the same arrangement of frames and running gear for either direct-current, single-phase, or three-phase motors. With such construction safe speeds are not limited to 15 miles per hour. Without it, track maintenance and liability to derailment would likely continue to be as disadvantageous to the electric locomotive at high speeds as they have in the past.

One feature of the author's description of the performance and rating of the locomotive motors which is of particular interest is that emphasis is put upon the continuous capacity, as well as the one-hour rating and the maximum tractive effort. In spite of the objections that have been urged against the term "continuous capacity" as applied to railway motor specifications, the author apparently takes it for granted that it is bound to survive; and it is to be hoped that its evident applicability to the specification of locomotive motors will lead to a more universal recognition of its appropriateness in specifying the smaller sizes of railway motors.

The author's estimate of the power station fuel consumption of these electric locomotives as compared with the Mallet compound steam locomotives, while interesting, would be more convincing from an economic standpoint if submitted in greater detail. The chief advantage of electric traction, demonstrated by the paper, is the increase of the capacity of the tunnel and adjacent mountain section, by doubling the speed possible with steam locomotives of the most economical type. Moreover,

there are still other operating features, such as the location of passing sidings, and the signalling and train-dispatching system governing the physical possibilities of getting the trains past each other at the increased speed, which have need of full consideration in order to determine the economic value of the increased speed made possible by the electric system.

F. S. Denneen: The chief reason for selecting the direct-suspension type instead of the more elaborate catenary type, now so popular, was the greater mechanical and electrical simplicity of the former. It is at once evident that with two wires over each track, with 6600 volts between them and between either wire and the ground, the problem of insulating the catenary type of construction would be a difficult one. With several tracks having numerous switches and intersections the problem would be greatly complicated. Within the tunnel the available head-room and side-wall clearance were so small that the catenary suspension was not desirable. With the speed limited to 15 miles per hour, many of the advantages of catenary construction over the direct-suspension type would be lost. A careful study of the entire situation then led to the conclusion that the direct-suspension type would fully meet all operating requirements, and, at the same time, because of greater simplicity, repairs could be much more quickly made, thereby reducing the danger of appreciable delays in the service.

The overhead structure in the yards on single track consists of the bracket shown in Fig. 20. It will be seen that each phase is supported by an independent span, and that auxiliary insulation is provided in every case; that is, the major insulation may be said to consist of the two heavy porcelain strain insulators marked *E* and the auxiliary insulation, the wood break strains marked *A*. The porcelain strains are rated for 10,000 volts, while the wood break strains might be rated at 3300 volts, or more. If I remember rightly in certain parts of the yards it was necessary to provide overhead construction for as many as six tracks; the details of the design work have somewhat slipped away from me, because it is more than a year and a half since I had anything to do with it. It was not possible to place any supporting means between the tracks and the entire overhead structure had to be carried on cross-span construction, which, because of its flexibility, made the insulation a difficult matter.

Fig. 17 shows that wires of the same phase are carried upon one cross-catenary, while those of the opposite phase are carried upon another one, also that there is insulation between the wires of the same phase over different tracks. This was done in order to make the tracks entirely independent, and to make it possible to cut out any one track or any set of tracks. Fig. 18 shows a unit system, that is, it is arranged so that by removing one or two bolts a new piece or a new unit can be quickly inserted without serious interruption to service. Adjustment by means of suitable turn-buckles is provided at every point where necessary.

Within the tunnel, the end-section of which appears as Fig. 21, the details of the overhead construction appearing as Fig. 22 and 23, bronze fittings were used in most cases. There was a great deal of moisture and drip, but it was not known how much of the moisture was due to the steam from the locomotives and how much from the drip through the tunnel roof. To provide against corrosion, bronze was largely used. Dr. Hutchinson says it is possible that malleable iron and steel properly galvanized would have done as well.

Dr. Hutchinson refers to the trouble experienced at the intersection of lines due to the trolley leaving the wire, this trouble occurring as the trolley wheel crossed the pan-casting. At the time the layout was originally made a scheme was considered for automatically turning the tongue portion in the pan so as to carry the wheel across in the proper direction, but this scheme complicated the arrangement and was not used.

When the original tunnel layout was made, the trolley wires were set 5 ft. apart, but after the designs had been worked out and approved by the railway engineers, the officials of the road decided that they wanted the entire central part of the tunnel clear, so it was necessary to set the trolley wires out to a separation of 8 ft. within the tunnel, which added a number of difficulties. The clearance between the side walls and the trolley on either side was only approximately 14 in., and as it was necessary to prevent the trolley from swinging, it was somewhat difficult to put in steady members with double insulation. The steady device used consists of two porcelain insulators of the ordinary skirt type of about 22,000 volts rated capacity, placed in series; the insulators are fastened together in a vertical position by means of a U-shaped casting with the ends cemented into the insulator pin holes. Each insulator carries a malleable iron cap, one of which is attached to the trolley wire and the other to the side wall of the tunnel. The connecting U casting is provided with a flanged portion all round, to protect the porcelain from blows from the trolley wheel. The large strain insulators used in the tunnel are capable of working at 20,000 volts, and the porcelain links at 10,000 volts; either could be broken,therefore, without interrupting the service.

It was the aim to provide against the likelihood of failure due to electrical or mechanical trouble with the insulation; for this reason heavier insulation was used than heretofore, for lines of this voltage.

W. I. Slichter: It is to some of the minor features and problems of the designing engineer, that I would like to call especial attention. The principal characteristic which differentiates American from European railway installations is size. Our trains are about three times as heavy as the European trains, and our heavy traffic over single-track roads requires that every operation must be performed with the utmost reliability to prevent costly blockades.

In the locomotives under consideration it was necessary that there should be developed a tractive effort about three times as great as that developed by the foreign locomotives, and the practice of pushing a 2000-ton train up a 2 per cent grade required that this tractive effort should be applied gradually, steadily, and continuously, as any sudden variations in a tractive effort of this large value would almost certainly result in breaking a train in two and possibly in causing a wreck. Thus the control system of such a locomotive is a most vital feature. There can be no reduction in the tractive effort after it is once applied, and there must be sufficient control-steps so that successive increments of tractive effort are not so great as to slip the wheels or strain the draw-bars to a dangerous extent.

These conditions rendered any scheme of double-speed connection, such as concatenation or changeable poles, undesirable, as in these it is necessary to cut out at least a portion of the motors while the change is being made. In this particular case the character of the service and the low speed of the locomotive eliminated the necessity of having more than one running speed. The problem was then to provide a control system which would give a steady acceleration and yet provide for running at fractional speeds for short intervals of time such as 15 min., as contrasted with continuous running.

This is accomplished by using plain rheostatic control in the secondaries of the motors, varying the resistance by contactors and providing sufficient capacity in the rheostats to permit of running for 15 min. at full load. Of course this means that the locomotive takes full rated power from the instant of starting; but the percentage of power wasted in this way is not great, as the running time is long compared with the time occupied in starting.

The control system consists of fourteen contactors per motor, five of which are in the primary, there being one contactor on one phase and two on each of the other two phases to provide for reversing the motors. This leaves nine contactors in the secondary to give thirteen steps, which is accomplished by a scheme of dividing the resistances into two or three groups, each having its contactor; and these groups are brought into different combinations so that each group is used over and over again, some times in series, some times in multiple with the others, and not left idle after being used once.

Of course this involves increasing the resistances unequally in the three phases, but this unbalancing has been kept within such limits that the torque per ampere is never less than 90 per cent of that with balanced resistances on all steps, and this loss is of far less importance than the inconvenience that would result either from increasing the number of contactors or decreasing the number of steps. As Dr. Hutchinson has said, an additional step has been obtained by closing the circuit at starting on two of the four motors before the circuit of the re-

maining motors is closed, thus the tractive effort on the first step is about 10,000 lb. and on the second 20,000 lb. and while accelerating at an average tractive effort of 37,500 lb. the tractive effort may be kept within the limits of 41,000 lb. maximum and 35,000 lb. minimum.

A separate and independent set of resistances is provided for the secondary of each motor to avoid the tendency of the motors to exchange current and " buck " when they are all connected in multiple to one set of resistances. If the driving-wheels were of exactly the same diameter, this multiple connection would act as a side-rod and tie the motors together; but as there are apt to be inequalities in the diameters of the different driving-wheels, a considerable load might be put on the motors in merely slipping the wheels to make them revolve at the same speed. As it is, the only effect of the existence of driving-wheels of different diameters is to cause a slightly unequal division in the load on the motors, which may be cared for by the auxiliary resistance referred to by Dr. Hutchinson. At the same time the natural tendency of the wear is corrective, tending to wear most on the larger wheel.

The advantage of the induction motor, due to its peculiar adaptability to regeneration, is best illustrated in this instance by considering the amount of energy which is regenerated and which would otherwise have to be dissipated in rheostats. To hold a train having a gross weight of 600 tons on a 2.2 per cent grade would require a resistance capable of absorbing 650 kw. per locomotive for the time during which the braking occurred. This corresponds, in size of rheostats, to the condition of running continuously at a speed of 4 miles per hr. with an input of 460 amperes per motor and a tractive effort per locomotive of 37,500 lb.

A very prominent feature of regeneration with the polyphase induction motor is the simplicity of its operation. As the greater part of the train gradually passes the summit and comes upon the down grade the speed gradually increases from 15 miles per hr., to 16.5 miles per hr., and without any attention on the part of the motorman the locomotives change their function from motoring to generating and from taking 1000 kw. from the line to giving back approximately 600 kw. Meantime there has been a tendency on the part of the generators in the power house and the water wheels to increase in speed with the speed of the motors on the locomotive.

This tendency is made use of by means of a centrifugal device to throw in circuit the water rheostat mentioned by Dr. Hutchinson, and located just outside of the power house. This rheostat takes the energy generated by the motors and holds the speed and frequency of the system down to normal. The water box is controlled in such a way that with a very slight increase in speed of the water wheels or generators the resistance is thrown across the generator bus-bars. When the speed has become con-

stant the resistance in circuit remains constant, and, conversely, as the speed decreases the resistance is drawn out of circuit. With a growth of the system and increase in the number of locomotives operating at once, this rheostat in the power station would be used less and less and more of the regenerated energy would be usefully employed.

E. F. W. Alexanderson: Looking at the design of the motors on the Great Northern locomotive as an induction motor, nothing new is to be found except in the proportions. In order to meet practical railroad requirements the mechanical clearance is three times as large as is usually made in a stationary motor of the same type, and twice as large as it has been made in certain well known three-phase European locomotives. As illustrating that the predetermination of the characteristics of induction motors has become almost an exact science, even when the proportions do not allow their derivation from other existing machines, it may be mentioned that the characteristic curves and overload capacity of the motor from test agree within the errors of measurement with the data submitted with the contract.

The interesting part of the problem in this case is the adaptation of the induction motor to railway requirements. The motor, as mentioned in the paper, considerably exceeds the specifications of capacity in continuous operation for a given temperature rise. In the case of a stationary motor of the ordinary kind, such a result would be a criticism of the design. With a locomotive motor it only emphasizes a fact borne out by experience in several instances, that the success of an electric locomotive depends more upon a certain balance of design than the ability to meet a definite service requirement; in other words, the maximum tractive effort of the motor must have a certain relation to the weight on drivers, and a locomotive motor that lacks overload capacity would be unsuitable even if it should meet the specified requirements in the most creditable way. Railway motors of the ordinary type are in most cases limited in capacity by the temperature-rise in service; this is substantiated by the fact that there is allowed a higher temperature than that found economical with stationary machinery.

The continuous capacity of such motors of the closed type is usually about one-third of the capacity for one hour, whereas, the continuous capacity of the Great Northern motors with forced ventilation is 79 per cent or 74 per cent of the hourly capacity at 500 volts and 625 volts respectively. In attempting to meet the Great Northern requirements, it was immediately apparent that a motor of any reasonable size would run too hot unless forced ventilation were used. It was naturally attempted to make the artificial cooling as efficient as possible by taking advantage of the structure of an alternating-current motor with distributed windings, thus bringing the air into intimate relation with the active parts. In order not to waste space

in the length-direction of the motor—which had already been encroached upon by the double gearing—the air is led through holes or channels running longitudinally through the core. This system of ventilation proved successful, and the tests show that the continuous capacity with forced ventilation is practically the same as the hourly rating on a standard basis without ventilation. It is most gratifying to see in Dr. Hutchinson's analysis of operating conditions that the design is well balanced, and that the continuous capacity is in proportion to the maximum work the locomotive may be called upon to do with a given weight on the drivers.

The weight-efficiency of the three-phase railway motor is often referred to. It might, therefore, be of interest to compare the Great Northern motor with two other well known locomotive-motors—the Detroit River tunnel locomotive (a freight locomotive of the same weight and mechanical design provided with four motors of the double geared type), and the Simplon, a well known three-phase locomotive. In the same table is shown the comparative figures for a stationary three-phase motor of the same dimensions. All three induction motors have practically the same armature peripheral speed, and the weight per horse-power is favorable. The Simplon motor is favored by a small air-gap, but handicapped by being wound for high voltage. No data are available for another three-phase railway motor with forced ventilation, but the capacity at 40 degrees rise of the Great Northern and the stationary motor gives a sufficiently good comparison. As might be expected, the weight per horse power in this case is somewhat greater for the railway type of motor on account of the air-gap being more than twice as large. The comparison of the four-motor types shows a relative consistency and also indicates the great possibilities of the inductive motor for high continuous output.

	Detroit River tunnel 600 volt direct current	Great Northern 625-volt three phase	Simplon 3000-volt three-phase	Stationary motor 550 volt three-phase
Weight	8330	12200	22000	11500
Air-gap		0.125	0.059	0.050
Peripheral speed in feet per minute	2450	3440	3250	3550
Horse-power hourly—75 degree rise	300	550	1100	——
Weight per horse-power	29.5	22	20	——
Horse-power continuous—75 degree rise	—	400	—	——
Weight per horse-power	—	30.5	—	——
Horse-power continuous—40 degree rise	—	260	—	330
Weight per horse-power	—	47	—	35

C. L. de Muralt: I am one of those who desire that each system shall have a fair show. I do not propose to advocate that any one system shall be used exclusively. The three-phase system has advantages which have already been thoroughly appreciated, and which will be more appreciated the more it is used, and I think it will be used extensively. But the other systems have also their advantages, and these systems will no doubt be continued to be used. It is for the broad-minded man to understand and realize and appreciate the advantages and disadvantages of each system. Engineers, in considering the electrification of steam railroads, must decide which system presents the greatest number of advantages and the least number of disadvantages in each particular case. There is no such thing as a universal system. There is no universal steam locomotive now. We might as well put forward one type of steam locomotive to haul all of our steam trains, as to put forward any one electrical system for hauling all our electric trains.

What Dr. Hutchinson brings out principally, to my mind, is that the efficiency of the three-phase system is extremely high. I have claimed that for some time, but have met many doubters. We have now an American example which shows conclusively that I actually underestimated the efficiency of the three-phase system. There is no other system that will show the same efficiency under the same conditions.

The recuperative feature has also been rather underestimated by me. Dr. Hutchinson's paper shows conclusively that the regeneration of the trains on the down grade is fully up to the calculated results. There is, of course, no reason why actual experience should disagree with calculations on this subject. But the full commercial value of recuperation has not been brought out. It cannot, because this is too limited an application of electricity. When the road is extended and operates over a longer distance it will show this also. In Europe, where roads are operating over long distances, with several trains on the line at one time, good use is made of the recuperative feature. Many mountain roads in Switzerland do not need any thing like the amount of energy that would ordinarily be required to propel the trains up-grade, because the power returned by the trains descending the grade helps out the power station.

Some engineers claim it is not good practice to use two trolleys. Unquestionably, one would be preferable; but two are used, and have been used for years, under conditions where switches are placed as close together as the tracks will permit, and these trolleys have been operated successfully. It is not an operating feature at all; it is a matter of suitable design, and proper location of overhead line. Once these are taken care of, the road will operate with two overhead wires just as well as with one. There is hardly any difference in maintenance either, because the main-

tenance cost is made up of labor rather than of material, and the same track-gang that must be kept waiting to take care of an occasional break on a one-trolley line will also take care of an occasional break on a two-trolley line.

The constant-speed characteristic is of course an engineering question, a question that needs to be carefully investigated in each particular case. It will not do simply to say that the series characteristic is advantageous. It may be so in many cases but not always. Sometimes it is disadvantageous, and for main trunk line operation I think it generally is disadvantageous. It is all very well to say that the constant-speed characteristic means increased power when the train runs at full speed up-grade. But those who have ridden up hill in an automobile, and watched the automobile slow down until it stopped, will want a constant-speed machine for grade work, and not a variable-speed machine. Of course when the locomotive does not do its work, it does not use any power. But the amount of energy consumed by a train running at slow speed and using small power, is not one whit smaller than the energy consumed by a train running at high speed and using big power, because the big power will be used for a shorter period only.

Calvert Townley: One point has not had as much emphasis as its importance deserves. The advantages of electric over steam traction and the possibilities of using mountain streams to supply electric power to the Western railroads have been much discussed on paper. Here is a case where the installation has actually been made. A large steam railroad, backed by abundant capital, and officered by men of high professional standing has electrified a section of its line at heavy expense. The type of apparatus selected, its performance, and characteristics, in which we, as electrical engineers, are natually much interested, important though it may be, is really secondary. The greatest importance attaches to the adoption of electricity to replace steam in this sort of service for the first time. It means more than any mere question of the electric system selected. We hope that this installation will be successful; that it will be extended; that the road will find the substitution of electricity for steam has been to its advantage; and that not only because of operating economies but also on other and broader grounds the value of this installation will prove to be so great that a distinct advance toward the electrification of important trunk lines will have been made.

I am personally pleased that we have at last in this country a three-phase installation for heavy railroad service, and from which we get such an encouraging report of early performances. The service requirements are well selected to favor this system, which certainly should do well here, if anywhere. It would be extremely unfortunate, both for those immediately concerned, as well as for every one else interested in the electrification of steam roads, if such an installation should partly or wholly

fail. The railroad world is quick to note success or failure, but slow to differentiate between systems or to accept explanations from interested parties.

Some matters in the paper are not entirely clear. First, what is the actual capacity of this locomotive? I note that the guaranteed performance of the motors before they were built was 250 h.p. each under continuous load, while after construction the tested capacity was 375 h.p., an increase of 50 per cent. In making this statement the author permits us to infer that there is a corresponding increased locomotive capacity. In another part of the paper, however, the transformer capacity is said to be smaller than that of the motors. The transformer rating is given at 400 kw. each, there being two supplied. If the transformer is limited to its rating, the continuous output of the motors cannot exceed 200 h.p. each, due allowance being made for losses; that is to say, 7.64 h.p. per ton total weight of locomotive. Even if the transformers can be made to carry 25 per cent overload continuously, and thereby permit the motors to be rated at their guaranteed capacity of 250 h.p. each, the horse power per ton becomes only 8.7, not as great as can be obtained with, for example, 25-cycle, single-phase motors. In view of this fact the author's second advantage of a greater continuous output than with any other type of motor would fail of demonstration. Further, if the tested capacity of the motors, 375 h.p. each, is to be made available, apparently the transformer capacity must be very materially increased. Additional or larger transformers probably mean a larger cab, heavier framing, and so on, and this of course changes the weight and upsets any direct comparison. It is not stated that the control apparatus, switches, and resistance are large enough to handle the current for motors rated at 375 h.p. each, or that the blowers have sufficient capacity to furnish additional air to the transformers. If these matters have been covered by tests, a statement regarding them would afford a better understanding of the claim for great power per small weight.

The claim for maximum electrical and mechanical simplicity is valid as applied to the induction motor, which should receive full recognition. However, the control apparatus, compared with that required by direct-current or by single-phase motors, is much more complicated. It is necessary to break twice as many circuits as with direct-current or single-phase motors. Instead of being more simple, therefore, the control part of the three-phase equipment would naturally be somewhat more complicated.

With reference to uniform torque, I ought perhaps to say that our observations on single-phase locomotive performances do not support the view that the so-called pulsating torque of that motor is practically in evidence.

Since practically all the single-phase installations in this country use the 25-cycle current, the author's claim that the

three-phase system has an advantage because it alone can use this frequency is somewhat puzzling.

The comment of a prominent steam railroad engineer on the question of constant speed was that the conditions which affect the operation of trains on schedules and which cause delays are many of them entirely foreign to any question of traction. Various and diverse influences cause delays, requiring trains to make up time if they are to be maintained on schedule. Therefore, an inflexible and a uniform speed is undoubtedly somewhat of a disadvantage even though the running time and operating conditions indicate that ordinarily it is desirable to maintain a uniform speed when the trains are running.

Ability to regenerate current by the three-phase system is of an undoubted advantage, and, naturally, will be used to produce a saving as the system is extended beyond its present limitations.

Charles P. Steinmetz: More than 15 years have elapsed since three-phase induction motors were first applied to railway work. Some years previously the single-phase commutator motor had been designed for railway work, but had not been used in practice, because there was no frequency low enough to make that type of motor suitable. A great deal of work was done on three-phase induction motors, a number of equipments were built, and high hopes were entertained that we were at the beginning of important developments in electric railroading. At the same time the synchronous converter was successfully developed and applied, its use enabling the operation of direct-current railway systems over such distances that the direct-current railway motor took care of all railway work for many years. For this reason the three-phase induction motor railway development did not progress in this country as it was hoped it would. The three-phase motor was used only to a limited extent, in mining locomotives, etc. Abroad, where prejudice retarded the introduction of the synchronous converter, considerable work was done in three-phase railroading.

Ten years after the early work the alternating-current railway motor was taken up again and the old single-phase compensated commutator motor was introduced industrially. Meantime it has developed so that to-day the single-phase motor is successfully applied to the solving of electric railway problems. At the same time most of us have begun to understand its limitations; it is not a universal motor, as its application is seriously circumscribed. The need of a frequency lower than the present standard as claimed by many designing engineers, limits the use of this type of motor. If it requires a system that differs from standard in all its parts—generators, transformers, etc.—this motor will be handicapped, because the economic development of the electrical industry must be towards uniformity in methods of generation, transmission, and distribution of power.

It seems now that the three-phase induction motor also has

reappeared and found successful application. The advantage of this type of motor is its simplicity and reliability, its uniform torque, and greater output for its weight. These are the characteristics of polyphase machinery. The main characteristic of the three-phase induction motor, however, is that it is a constant-speed motor. From this feature follow most of the other characteristics: the relatively low efficiency of acceleration; that it consumes the same power in turning round slowly as when running at full speed at the same torque. A result of the constant-speed feature is the automatic regeneration of power above synchronism. We can improve the acceleration by concatenation, or, as it is called abroad, cascade connection, or by changing the number of poles. The repulsion motor or any alternating-current commutator motor can be made regenerative, but this means additional complication, which to my mind is undesirable in railway work.

The constant-speed feature limits somewhat the general application of the three-phase motor to railway work. It is well suited for mountain divisions, for running continuously with heavy torque, positive or negative. The successful application described by Dr. Hutchinson is on a mountain division. Another application would be for very high speed passenger service. At speeds of 50 or 60 miles an hour, or more, the air friction produces a considerable part of the train resistance; there is a decrease of the difference between the power required to run on a level track at a constant speed and the power of acceleration, and, therefore, an approach to the same conditions as running on a mountain division.

For general railway work, however, as at present carried out in this country, the three-phase locomotive is not as well suited as the direct-current locomotive or the single-phase locomotive, for the reason that the direct-current series motor or the alternating-current commutator motor can directly replace the steam locomotive in present railway operation, while the three-phase induction motor locomotive is not at its highest efficiency, when operating on a railway system under existing conditions. The method of operation must be rearranged to a constant-speed service. Whether the constant-speed operation of the railway would be disadvantageous, or advantageous, over the present variable-speed method, requires further consideration. At present we are inclined to consider it as a disadvantage; the present varying speed method as preferable. If the steam locomotive slows down on an up-grade, or loses time at a station, it can make it up on the level track by speeding. At the same time, if the traffic is unusually heavy, the steam locomotives cannot make schedule and all schedules are upset, and just when we need the full capacity of the railroad system most, the operation of the railroad is at its worst, as we have seen more than once.

In a broad study of the railway problem we have to investigate whether the method now in use is really inherent in the problem,

a necessary requirement of the desired results, or whether it is an incidental feature of the particular apparatus we use. The steam locomotive is a constant-power motor. It gives approximately the same power irrespective of the speed, the power as limited by the steaming capacity of the boiler. Whether there is a heavy grade or a run on a level, there is a definite power limit, and this condition has brought about the present method of railway operation. It was the necessity of making up for lost time, as the locomotive has to slow down on up-grade, because it can not keep up steam when running as fast on a grade, as on a level track. With a different type of motive power, however, it would be well to investigate whether there would not be an advantage in rearranging the method of operation to suit the characteristic of the new motive power. It is quite likely that the capacity of any railway system could be greatly increased if we could get really constant-speed operation irrespective of grades, loads, etc. Possibly at constant speed much greater passenger traffic and much greater freight traffic could be handled. All these problems require impartial investigation by engineers that are not in favor of any one type of motor, or of the steam locomotive; engineers that would consider the entire railway problem, and find a solution for increasing the capacity of existing steam roads.

As regards the limitation of the shunt motor, I wish to draw attention to one particular feature: when we speak of the shunt motor, or the induction motor, we always exclude the rapid transit service, from its field of use. We consider rapid transit as that class of service where the series characteristic is especially necessary and to which the shunt motor is especially unsuited. The most extreme case of this intermittent service, acceleration at heavy torque and no constant speed running—the most extreme case of rapid transit—is the high-speed passenger elevator. This service is now always operated by the induction motor and the shunt motor, with or without compound field. It is rather interesting to see that where no precedent limited the character of operation, in the extremest case of rapid transit, motors of shunt characteristic have been chosen for the sake of service capacity, reliability, and safety.

Carl Schwartz (by letter): The operating conditions as presented by Dr. Hutchinson seem to indicate that the three-phase system is well adapted to the service, its few inherent disadvantages being overbalanced by its advantages.

In previous considerations of various systems of electric traction considerable attention was given to the design of the locomotive, the characteristics of the motors, and comparatively less to transmission and generating systems. While the locomotive is a very important part of the whole, both the weak and the strong features of an electric traction system are only in part determined by the characteristics of the locomotive. The decision as to which system is best to adopt may be influenced very much by other considerations.

One of the first advantages of the three-phase system in common with the direct-current system is that the generators are not subjected to such extremely heavy strains as are incidental to single-phase operation. In case of the Great Northern Railway Company's electrification current is generated at 6600 volts, transformed at the power house to 33,000 volts, this pressure is reduced at the substation to 6000 volts, and fed to the trolleys and the track rails. The intermediate transformers are a very important element in the system, and, together with the fact that the system is three-phase and not single-phase, explain the freedom from generator troubles.

Under present conditions we understand that one important feature of the three-phase system, the recuperation of energy from trains going down-grade, cannot be taken advantage of. This advantage, of course, exists only if trains are in service simultaneously up- and down-grade, so that there is load to carry at the switchboards for the train going down grade and returning power back to the station. This condition can ordinarily only be met by an installation of sufficient size, unless the schedule is so arranged that trains will travel up- and down-grade simultaneously. If this is not the case the power returned by a train running down-grade will have to be absorbed by automatically regulated rheostats which thus simply replace the mechanical brakes on the locomotive and dissipate the energy.

I investigated in detail sometime ago the merits of the three-phase system for a tunnel electrification in the Middle West where no water power was available. I found that the same conditions eliminated the feature of power recuperation, and, in this case, the only reason remaining for possible selection of the three-phase system. The result was the selection of direct current with a storage battery to equalize the load.

The operating conditions in the generating stations are stated to be very irregular. The generators may carry full load for, say 15 minutes and then run idle for several hours. Outside of bad regulation the objections against such intermittent operation are not great, but the operation would become extremely wasteful in case of a steam generating station and would show results on the coal pile that would exceed the consumption of the Mallet type locomotive.

Dr. Hutchinson calculates the equivalent consumption of a Mallet compound locomotive at 8 lb. of coal per kilowatt-hour. In case of the three-phase system he assumes 3 lb. of coal per kilowatt-hour at the bus-bars, or 4.28 lb. at the rail, taking the total efficiency from the station bus-bars to the rail at 70 per cent. The consumption in a modern steam station is two or three pounds per kilowatt-hour for a load-factor of, say, between 60 per cent and 40 per cent, but not for operating conditions similar to the Cascade Tunnel electrification. I do not desire to predict any figure for coal consumption in this case, but it will be above 8 lb. per kilowatt-hour, as in the case of the steam locomotive, and not below.

Any other system than the three-phase would under the same conditions not show better results, as the question of coal consumption is influenced more by the load characteristics than by the few per cent difference in efficiency between rails and station bus-bars. The traffic will have to be materially greater to approach a consumption of, say 3 lb. of coal per kilowatt-hour or one-half that of the Mallet compound locomotive.

Dr. Hutchinson has enumerated under the disadvantages "the constant speed of the locomotive" but he himself sees this characteristic rather as an advantage. Constant-speed characteristics of the locomotive motor on a mountain division is apt to accomplish one thing which other systems than the three-phase will not do; that is, allow close adherence to the schedule, which can be made more uniform than for steam service. While there is no possibility of making up lost time there is less possibility of losing time. As the speed is limited by the amount of traffic possible to handle up-grade on the division, the average speed will be increased. This means a proportionate increase in the capacity of the road and may in some cases eliminate the necessity of double-tracking.

Some of our Western roads may find this feature a sufficiently strong impetus to induce them to electrify, even if the power house should not show one-half the coal consumption of the Mallet type of locomotive. Furthermore, this item of energy consumption, as far as station economy is concerned, disappears more or less if water power is used. The only feature remaining is some possible increase in capacity of the power and transmission system, which may not be too expensive on account of the short duration of the peaks.

The three-phase system installed for the Great Northern railway by Dr. Hutchinson is the first three-phase railroad electrification in America, and there seems good reason to believe that this example will go far to secure for the three-phase system in this country the place it deserves.

Frank J. Sprague (by letter): The present is no time for arbitrary statements as to the supremacy of any one electrical system, but rather for that catholicity of view which admits of a variety of effective solutions for many problems, even if for others some one system may offer a preponderance of advantages. I shall, therefore, express no special views on the relative merits of different systems, except that I am glad to note that my efforts in behalf of the adoption of interpole motors and 1200-volt, direct-current operation, with both overhead and third-rail conductors as one of the possible alternatives, have received the practical endorsement of adoption and a rapidly widening application, thus giving the electrical engineer an additional lever for attacking the electrical transportation problem on a large scale.

Without discussing earlier installations, it is of interest to note that so far as at present developed this Cascade Tunnel

installation is one of three in this country of almost identical requirements; that is, operation through a tunnel of heavy freight and passenger trains on severe grades at moderate speeds. Each of these is characterized by a different electrical system. Two, the Sarnia single-phase and the Cascade three-phase, are in operation, while the Detroit Tunnel direct-current locomotives have been fully tested. In each case the steam locomotive could only be used under the maximum disadvantages, the very worst possible conditions. Adoption of electrical operation by almost any method offered an effective remedy, and it is an encouraging fact that each of these installations overcomes many difficulties incident to steam operation under certain limitations, and that we have as a result higher speeds, greater capacity, and increased safety and cleanliness.

But none of these installations represents trunk line requirements under conditions which exist on many of our roads. It has been my fortune to have for nearly three years made a study of such a trunk line, presenting what I consider perhaps the most difficult operating problem I have ever encountered. I refer to a stretch of nearly 140 miles on the Sacramento Division of the Central Pacific Railroad, over the Sierra Nevada Mountains. There is much about the investigation of this which it would not be proper for me to touch upon, and I will only refer to it in a brief way.

The section in question is normally single tracked, with sidings every few miles which raise the aggregate trackage to something over 200 miles. The physical conditions are such as to present extreme difficulties to double tracking, although second tracking is being added for a part of the distance. There are nearly 32 miles of snowsheds and tunnels, and in winter the snow sheds form practically continuous tunnels. The grades are severe, there being a rise of about 7000 ft. in 83 miles in one direction, with a ruling grade of 2.4 per cent, and the amount of curvature is startling.

Over this division practically the entire freight and passenger traffic from the Union Pacific Railroad for Central California passes. Freight trains, often over a third of a mile in length, and with 2000 to 2500 tons trailing load, are operated in both directions. These trains require as many as four consolidated locomotives, or two of the heaviest Mallet compounds. The running speed is sometimes as low as seven miles an hour, and the schedule speed for the division is seriously interfered with by opposing traffic. Coupled with this freight operation is passenger operation in both directions, in trains up to nearly 400 tons trailing load, way trains, "limited," Pullmans, and fast-mail trains, operating at double the freight speeds, and with coasting speeds as high as 50 miles an hour.

This division is approaching the limit of steam capacity, especially when considered in relation to the balance of the system, and the question is whether such a division can be

operated electrically, and if so, what can be gained thereby. Would the object be economy in fuel? Such alone would not warrant electrification, although the general line of investigation of railroads operated by electricity will show about 50 per cent in coal economy. If carried out, electrification will be primarily for the purpose of increasing capacity, and thereby effecting ultimate economy.

The specifications already issued require operation on this road of 2000-ton trains at 15 miles an hour on a 2.4 per cent grade, and 400-ton passenger trains at twice this speed. This last condition involves a much larger motor capacity at the head of a passenger train than the gratifyingly large capacity exhibited by the locomotives of the Cascade Tunnel, not in tractive effort, but in the product of tractive effort and speed.

The investigation of the possibilities of electrification on this road have been conducted on a plan somewhat different from that ordinarily taken. It was not deemed wise first to decide upon a system, but rather to ascertain the costs of locomotives by various systems which could perform a service determined as essential to effective operation, and then to collate all the facts, advantageous and otherwise, affecting capital cost and cost of operation, after which the best system to meet the existing conditions could be determined.

If asked what system would probably be indicated, I must frankly say that I do not know. That electrification is possible I do know, and that such can be successfully carried out I do not doubt, with increased capacity and general economic results. That it will be so done I also firmly hope and believe, but I am impressed with the absolute necessity that in considering a problem of this character, as well as all problems which are continually confronting the electrical engineer, there is no development which can be reasonably undertaken which should be curtailed, and none which should be disregarded.

We are passing through that inevitable stage of development and elimination essential to final correct decisions and permanency of results. However critical, therefore, I may sometimes feel as to the inadequacy of any system in some particular application, I welcome every installation which promises to further the effective and economic application of electricity to trunk-line operation.

Discussion at Minnesota Section, November 18, 1909.

Edward P. Burch (by letter): The writer made a study of the Cascade Division of the Great Northern Railway, including the Cascade Tunnel, and reported on its electrification to the Great Northern Railway Company, in January, 1904. The report was on the power problem, the mechanics involved, the available water power, the advantages of electric traction to prevent congestion of traffic, and finally on the net saving which was possible. The latter was corroborated by the record made

by the general manager. It was recommended that a commission be appointed to study the subject as the responsibility for selecting a definite electric system for the whole division was large. The only precedent for the work was at the Baltimore and Ohio Railroad tunnel, where there were hauled many more freight and passenger trains per day up heavy grades and with great satisfaction, after the third-rail was installed.

The electrification of the Cascade tunnel itself was an exceedingly simple piece of work, but the electrification of the Cascade Division from Leavenworth to Everett, 109 miles, involved many problems not yet solved. The electric system and the locomotives were to be suitable for, and interchangeable on, the entire division, not for the tunnel only.

It was well known that no electric system was offered by American manu acturers for real railroading on these mountain grades; and experimental work was not welcomed on so large a scale. President Hill's decision was that the new Mallet compounds should be tried out.

The great objection to the use of three-phase power for railroad work is due to the necessity of carrying two overhead conductors; nor is this a minor matter in railroading. The delivery of power from a contact line to the locomotive is of vital importance and must be made absolutely perfect. Two overhead conductors in railroading, around freight yards and terminals, do not promote simplicity. It is not possible to carry two overhead wires with a difference of potential of 6,000 to 11,000 volts, above the many switches at yards and sidings which are most common in railroading, and make a rugged construction. Long, expensive, and complicated section-breaks are not desirable.

In practice the alignment of American track is not good. Further, the distance between the rail and the trolley of American roads will be from 22 to 24 ft. as a minimum, where European practice shows from 14 to 18 ft. Track irregularities cause the deflecting force at the upper end of the pantograph or trolley wheel to vary about as the square of the height. In railroading it will not do to have the trolley flop off, partly because it will be dangerous in ordinary operation. When there are two or three locomotive units to a train it is absurd to think that locomotive men will give attention to four trolley poles, turning them when the direction is reversed. A pantograph is necessary, but it is not possible to run a pantograph over rough switchwork at good speed without danger of short-circuiting the two trolley wires. A difference of potential of 6,000 to 11,000 volts will be used in heavy electric traction.

Modified systems may be used for mountain grades; namely:

1. The use of two trolleys for slow, three-phase freight locomotives; and the single-phase system, using one of the two overhead trolleys, for passenger service, for simplicity, variable speed, and rapid, efficient acceleration.

2. A single-phase, 11,000 volt trolley line and a rectifier on the

locomotive delivering 600-1200 volts direct current for motors. This wou'd make an interchangeable system.

3. Three-phase generation, single-phase utilization from a single contact line, and the H. Ward Leonard scheme with the high-voltage, high-speed, light-weight, single-phase motor-generator which will drive the axles through intermediate low-voltage motors.

4. The use of the three-phase system with two trolleys for heavy grades, and the use of three-phase motor as a single-phase motor from one trolley at all sidings, yards, terminals, shops, etc., in slow speed and light switching work, for simplicity and safety.

Max Toltz (non-member): In regard to the details of the electric locomotive. Transmitting the power by gears from the motor to the axle is street railway practice and is not as good as side-rod construction. The gear transmission with which the Great Northern electric locomotive is equipped makes it unhandy to inspect the apparatus, or to repair motors or to inspect accessories, because it will be necessary to lift the cab and pull the truck from under and then raise the motor, etc. With the side-rod construction smaller wheels can be used, and, instead of four motors, two motors need only be installed above the locomotive frame. This has also the advantage of locating the collector rings where they can easily be inspected and repaired.

The motors should be wound for at least 3000 volts, instead of 500 volts and the former voltage should be also carried by the trolley wires. In that case the transformers on the locomotive between the trolley wires and the motors would be eliminated— a step towards simplification —and at the same time the electrical losses due to transformers will be cut out.

Instead of trolley poles with wheels, bow trolleys with roller contact for each wire could be used having the advantage of overcoming the present trouble of the trolley wheel jumping trolley wires when going in either direction.

An automatic device similar to the one used on the Valtallina electric three-phase locomotives should control the current supply to the motor instead of the common step-down rheostat.

A single speed in the motors is satisfactory for the tunnel operation, but if the whole Cascade division is to be electrified two speeds will be necessary, so that trains going down grade may run at a higher speed.

The transmission lines between the power house and the sub-station would be more reliable if each circuit had its own pole line, one on each side of the railway, for a slide or a falling tree would not put the line completely out of commission.

Trolley wires suspended from messenger cables would withstand harder usage in heavy operation.

In regard to some of the data given in Dr. Hutchinson's paper, exceptions should be taken. The rail resistance is given at 6 lb. per ton, which under the very best of conditions of rail

and equipment if 6.5 lb. Dynamometer tests give 6.5 to 14.25 lb. per ton. In the tunnel with its soot and wet rails the resistance used to be over 10 lb. per ton.

The rail resistance of the Mallet locomotive is stated to be 47 lb. per ton, computed from ammeter readings. This figure is much too high, and is probably due to the air pump action of the pistons in the cylinder. It is assumed, of course, that the throttle valve was closed with the reverse lever being in the forward corner notch. It should be borne in mind the cylinders of the Great Northern Mallet locomotive have no by-pass connection, but are equipped with valves, one at each end of the cylinder.

The following results were obtained from tests in which indicator cards were taken simultaneously on all four cylinders of the Mallet, on a level track:

Type of locomotive	Locomotive weight	Miles per hour	Horse power absorbed	Resistance lb. per ton
Mallet	250 tons	8	57 h.p.	10.8 lb.
"	250 "	10	74 "	11.2 "
"	250 "	12	95 "	12.7 "

If Mr. Emerson had given the coal consumption per 100 ton-mile-hours instead of 100 ton-miles the results would have been somewhat different. The writer assumes, therefore, that Dr. Hutchinson's calculations are based upon a speed of 7 to 8 miles per hour, but calls attention to the fact that the most economical work of the Great Northern Mallet is performed at about 11 miles per hour.

The minor advantages of electrification as explained should be called " major " advantages but to these should be added:

1. The saving in locomotive ton miles due to the elimination of the tender of the steam locomotive.

2. The mileage of the electrical locomotive will also exceed that of the steam locomotive, because the engine need not go to the round house for boiler repairs and need not be turned.

3. The best showing of the electric locomotive as compared with the steam locomotive will be made during the extreme cold weather when the latter will fail in generating the usual quantity of steam, while the former will not be hampered by any temperature prevailing in this country.

4. Also the elimination of all water and coal stations should not be overlooked.

The steam locomotive cannot expect to equal the record made by the New York Central locomotives of only 14 minutes delay in 80,000 train miles.

E. Marshall (non-member): On down-grade through the tunnel the crews were at first afraid to trust to regeneration by

the induction motors to do the braking, but a few trips were sufficient to reassure them. The trip through the tunnel is now entirely devoid of danger from this source.

There have been only a few failures due to the electric locomotives. In one case some of the resistance grids were burned out, but the locomotive could be operated. In several cases of overloaded motors the secondary leads of the motors were melted from the rings. Due to inaccessibility, the repair of these motors is a difficult task.

The system of current collection by means of a wheel trolley and overhead wires strung similar to street railway lines is not satisfactory. Trolleys leave the wire, tear down the overhead work, and sometimes are the cause of a train breaking in two, due to relieving the load on the locomotive. In case of change of direction the trolleys must be changed; this is sometimes forgotten and the overhead construction suffers in nearly every case. On account of the 5 ft. spacing of the wires in the open, and 8 ft. in the tunnel, the pantograph cannot be used. It is probable that the overhead work will be changed to catenary construction and bow collectors used, as there is no question about that design being more satisfactory.

On the whole the operation of this system is most satisfactory. The above remarks are not made as criticisms but are mentioned to show that the defects are no greater than one has a right to expect in a system where precedents are so few. Everyone connected with the operation of this system is anxious to see it extended to take in at least all of the track having the 2.2 per cent grade.

Cary T. Hutchinson: I am gratified to see that there seems to be a very general agreement with me that the three-phase system was well adapted for use in this particular place. I believe nearly all of the speakers have assented to this.

I find in the discussion a number of points in which the various speakers differ from me in regard to details, and it is very probable that they may be right and I wrong. I do not think it necessary to discuss these points, but wish merely to answer the questions that have been asked.

In reply to Mr. Katté. The ground wire was omitted as there is no lightning on this side of the mountain. My reasons for saying that probably a three-phase system would have been used even though only the tunnel were under consideration, was because of the far greater capacity of three-phase motors as compared with direct-current motors in the same space, and the lesser cost of construction and operation. Wooden poles were used, as they could be obtained very cheaply and of extremely good quality.

Mr. Arnold and others question the high frictional resistance of the Mallet locomotives. I can only say that these tests were carefully made by competent observers, and I am sure are ac-

curate expressions of the conditions that existed. I of course do not pretend that the internal losses of the Mallet, when operating under its own steam, are represented by these figures; there is no direct comparison between the two conditions.

I do not think that the method of control used on the Italian State Railways referred to by Mr. Waterman would be satisfactory under the conditions of a Western railroad in this country where it would be fatal to install any apparatus requiring careful supervision of operation and maintenance. Everything must be of the sturdiest character, and as nearly as possible "fool-proof."

Mr. Pomeroy gives some very interesting results of coal consumption of heavy locomotives on mountain grades. It should be noted that Mr. Pomeroy shows the coal consumption to be nearly twice as great as I deduced from Mr. Emerson's statements, amounting to from 13 to 19 lb. per kilowatt-hour as compared with 8 lb. Mr. Pomeroy also brings out the very interesting fact that the coal consumption in operation is just double that deduced from test results. I had also arrived at the same figure by the comparison of records of operation with special test runs made on hills—such runs are practically of no value in determining coal consumption.

I agree with Mr. Smith and with others who state that the collection of the current is a very important factor in deciding the type of machinery to be used. The use of the trolley wheel in this particular case was forced upon me, and was not my deliberate choice, as the officers of the road would not permit encroachment upon the overhead space in the centre of the tunnel. It is not at all improbable that some change may be made in this, particularly if the system is extended, and a pantograph may be used.

I am also glad to see that Mr. Smith, in common with others, approves the rating of an electric locomotive by its continuous duty. This seems to be the only sensible way to rate any piece of electrical apparatus, even though it is used in intermittent service. There will of course be all sorts of intermittent service, and the ratio between the actual service and the continuous capacity must be determined for each particular case. A motor, however, having a greater continuous capacity will, other things being equal, be the better motor for any service. Other methods of rating railway motors serves principally to conceal the facts.

Mr. Denneen has emphasized some of the reasons for the use of special features of the overhead construction. In this, as in other matters, I can only say that all the details of this subject were carefully considered.

Mr. Townley questions the continuous capacity of locomotives on the ground of the lower rated capacity of the transformers. It is true that the rating of the transformers is only 800 kw., continuous, with the quantity of air specified but the transformers have an overload rating of 100 per cent for one hour.

For the service that the locomotives are now employed in, the transformers have ample capacity, and there is space enough either to install larger transformers in case they are needed for the extended service under contemplation; or what would be simpler, increase the quantity of air to these transformers. This has been done on test. There would be no difficulty by one or the other of these methods in making the transformers equal in continuous capacity to the motors and rating the locomotive at something over 1100 kw. continuous. The control apparatus has been operating regularly at much greater power, and there will be no difficulty at this point. The motors themselves are the limitation to the capacity of the locomotive—not the transformers, nor the subsidiary apparatus.

Mr. Schwartz is of course correct in stating that the coal consumption of a steam station, operating as the Tumwater station is now operating, would be much greater than 3 lb. per kilowatt-hour and might be almost anything. My comparison was not intended to refer to existing conditions but to the service as it would be when handling the entire traffic of this mountain division, and the traffic so arranged as to secure a reasonably good load-factor at the power station, which I regard as an essential to the electrical handling of any train service. In other words, when a division is electrified, the train dispatching must be conducted in accordance with the exigencies of the power station; the cost of any other method of dispatching will be so great that railroad officials will readily agree to this limitation.

If, however, Mr. Pomeroy's figures represent more nearly the coal used in steam service, as I believe they do, then it is not at all certain that a steam station would not give better coal economy, even if operating under as disadvantageous conditions as now exist at the Tumwater station.

Mr. Toltz gives some interesting figures for the frictional resistance of Mallet locomotives based on the indicated power in the engine cylinder. As I have said above, there is no necessary connection between the power so used and the power required to tow the same locomotive. I do not, however, think that much reliance can be placed on indicator cards, taken under the conditions described by Mr. Toltz. It is to be noted that the figure he gives for the total resistance of the locomotives, of say 11 lb. to the ton, is about the same as he states the rail resistance should be, which he gives at from 6.5 to 14.25 lb. per ton. The 6 lb. to the ton that I used was given me by the chief engineer of the railroad.

Mr. Marshall has referred to some accidents to the overhead structure, due to trolleys leaving the wire. This has been due largely to the impossibility of keeping this overhead structure in proper alignment, owing to the fact that little or no time can be found for working on this structure, on account of the exigencies of the train service.

Discussion on "Telegraph and Telephone Systems as Affected by Alternating-Current Lines." Boston Section, October 20, 1909

(*Subject to final revision for the Transactions.*)

A. S. Richey: My experience in this connection has been almost entirely with the private or operating telephone lines of electric railways. In such cases the telephone lines have been strung on the same poles that support the trolley wire, direct-current feeders, or alternating-current transmission lines. In most instances all four classes of wires were carried on the same pole line. In my first telephone experience in connection with three-phase transmission lines the alternating voltage was 16,000, and our telephone construction (perhaps blindly) followed the old practice where the only interference was from 600-volt. direct-current trolley and feeder. The two telephone circuits, extending about 100 miles, were alternately transposed every half-mile, and the jack-boxes, located at about quarter-mile intervals, were simply wooden boxes with the bottom and lower front entirely open to the weather. The operating contacts were brass posts mounted right on the wood, and consequently formed a pretty good ground on the telephone circuit every quarter-mile. Due to the fact, however, that the ground was the same on each side, the telephone circuit remained in balance, and we got very good results. Our aim in the maintenance of good telephone service was, as Mr. Taylor recommends, "to keep the line in first class condition." Our greatest trouble in so doing was in equalizing the resistance and insulation of both sides of the circuit. Poor electrical connections at joints in the wire affected the first, while tree-grounds, principally, affected the second condition.

Later on, in building another 125 miles of transmission line, the voltage in this case being 30,000, the telephone transpositions were made on a single insulator without cutting the line wires. This greatly reduced the number of joints, and not nearly so much trouble was experienced from loose connections. I have attributed our good service on these telephone circuits: first, to good construction and careful maintenance; secondly, to the fact that the partial ground on both sides of the circuit at every jack-box brought the line, electrically, very near the ground; thirdly, to the probable shielding effect of the 600-volt, direct-current feeder which was carried on the same cross-arm as the telephone circuits.

In most of my experience "the disturbers and those disturbed" have been one. In the operation of several hundred miles of interurban railway, where the train despatching and a great part of the company's business communication between stations, offices, power stations, and sub-stations is done over telephone lines which parallel the company's own transmission lines, the telephone is, in a way, as important as the transmission line—at least one can not well be operated without the other. In such a situation the operator is as much interested in the dis-

turbance as in the disturbing influence, and he must solve the problem.

I think that some protective apparatus such as that described in the paper should invariably be used whenever, as is the case with most transmission lines and interurban railways, telephone wires are carried on the same poles with high-voltage transmission lines.

Sewall Cabot (non member): I should like to point out that where telegraph lines are run on a metallic basis it would be necessary to establish repeater stations wherever it is desired to connect the lines with existing lines run on a ground-return basis. In the case of the telegraph systems on a multiple basis shown in Fig. 5, I should like information concerning an actual test of this method of operation, as in practice I think it would considerably slow down the speed of transmission.

I think there is an error in the direction in which the dynamo is shown connected in diagram *E*, Fig. 5. If connected as shown there would be no potential difference to operate the instrument in the middle of the line.

I should like information regarding the commercial feasibility of transposing the three-wire trolley system mentioned in the paper, so as to render the telegraph and possibly the telephone lines immune from inductive disturbances.

John B. Taylor (by letter): The form of telephone transposition referred to by Professor Richey, as made on a single insulator, has come into general use because it is superior to the old form involving several joints in the line. In some cases a telephone line on brackets has been transposed without cutting the line or making use of special transposing insulators, by placing the two brackets on opposite sides of the pole at the transposition point and spiralling the line one-half turn.

Mr. Cabot has raised some practical working objections to the metallic-circuit multiple telegraph system, and as far as I am aware such a multiple system has never been given a commercial working trial. He is correct in assuming wrong polarity indicated on one of the generators in diagram *E*, Fig. 5. This will be changed.

The three-wire trolley system would naturally be undesirable from the railroad man's point of view. The great difference of potential between the two trolley wires (double the normal working voltage from each wire to ground) would make the general insulation question more difficult, and still further objections and difficulties would be introduced at transposition points requiring section insulators. This and other schemes shown in the paper are given merely as indicating lines of action tending to improve matters. The conditions are always so variable as regards both the transmission and signalling systems that what might be considered impracticable in one case might be found feasible in another.

NOTE.

On pages 76 *et seq.* of this PROCEEDINGS will be found the discussion on Mr. Doherty's paper "Comments on the Development and Operation of Hydroelectric Plants", contributed at the meeting of the Institute at New York, December 16, 1909. The High-Tension Transmission Committee, under whose auspices the paper was presented, invites further discussion from any member who may feel so inclined after reading the discussion printed herein. Additional discussion should be sent to Ralph D. Mershon, Chairman of the High-Tension Transmission Committee, 60 Wall Street, New York, not later than April 10, 1910.

Discussion on "Comments on the Development and Operation of Hydroelectric Plants." New York, December 16, 1909.

(*Subject to final revision for the Transactions.*)

President Stillwell: There is no other subject at the present time within the horizon of the electrical engineer which involves so many important questions, both technical and financial. As you all know, the Federal Government and various State Governments have under consideration various plans for limiting the appropriation of water powers by private individuals and corporations Every electrical engineer with whom I have talked upon the subject approves in principle the idea of allowing appropriation only under a franchise which limits the term of use by the corporation or individual receiving the appropriation, but there is a great difference of opinion as to means and methods. The prospectus of the promoter who, in setting forth the advantages of these proposed developments, has not failed to emphasize all of the financial possibilities, is responsible for a general misconception on the part of the public and on the part of some of our Government officials in regard to the financial returns of these water-power developments. In a conference only two weeks ago, a prominent official of the Federal Government who is giving attention to the subject remarked that he had examined the prospectuses of certain water-power projects recommended by banking firms, in which it is stated that profits of from 30 to 40 per cent were certain. On the other hand, if we look around we find a large number of the more important water-power developments which have been attempted in the last 5 years in the hands of receivers. Of course there are water powers, especially in the West where coal is expensive, that have made large returns in proportion to the investment; but on the average these enterprises which are directly essential to the successful prosecution of a real policy of conservation have not succeeded financially. True conservation, of course, demands the most prompt possible utilization of our water powers, consistent with due regard to the rights of the people as a whole in this property, which belongs to them, and which should be safeguarded in their interests; but whatever arrangement is adopted, it should be such as to attract and not repel capital, if we are going to utilize with the greatest possible promptness these solar engines and conserve our fuel supply, which, as we now use it for power purposes, is burned at an enormous sacrifice.

Henry G. Stott: I am going to try to confine my remarks to only one portion of the paper, and that is to the question of the use of a steam plant as a reserve, and what proportion that steam plant should be to get the most economical results. Usually all engineering questions are finally solved by compromise. There are very few cases in which we find that we can solve any engineering problem on theoretical principles, as financial or com-

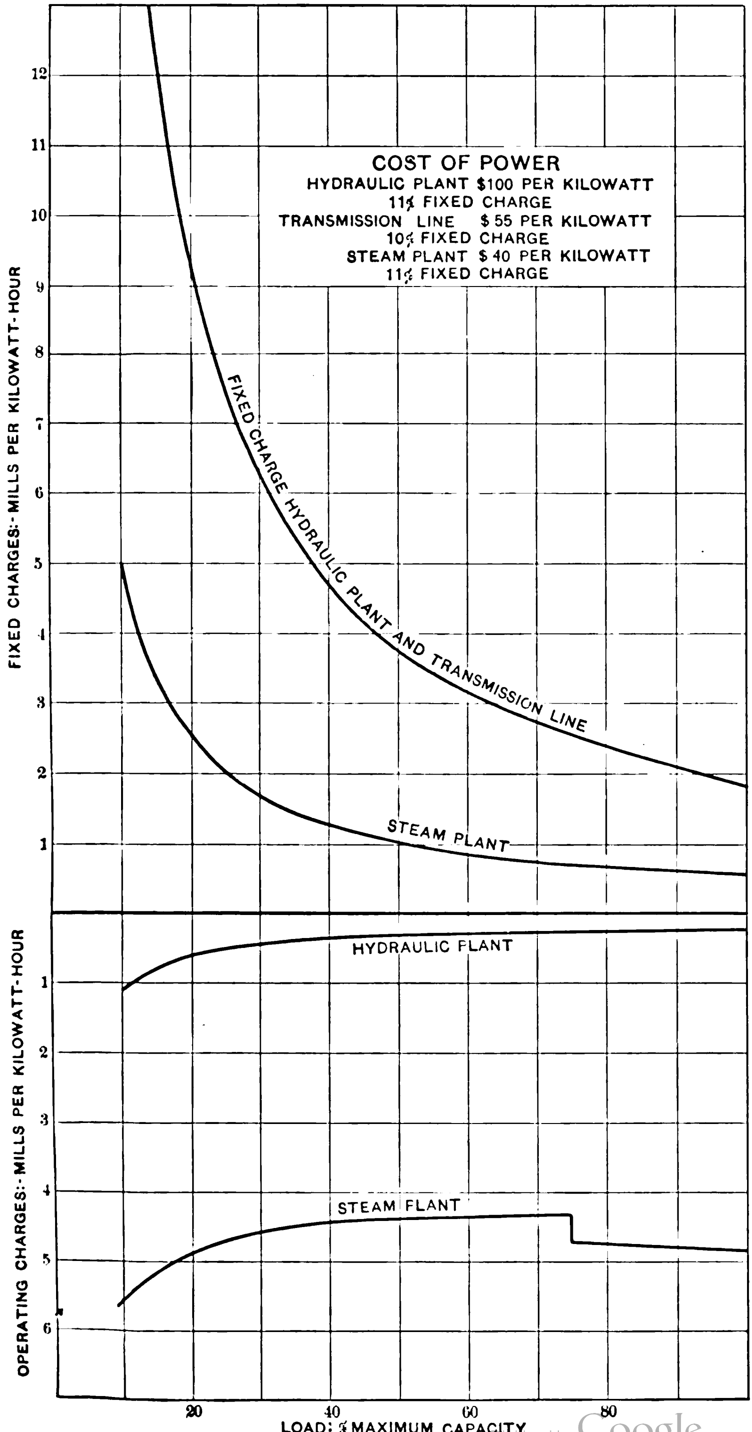
COST OF POWER
HYDRAULIC PLANT $100 PER KILOWATT
11% FIXED CHARGE
TRANSMISSION LINE $55 PER KILOWATT
10% FIXED CHARGE
STEAM PLANT $40 PER KILOWATT
11% FIXED CHARGE
FIXED CHARGE HYDRAULIC PLANT AND TRANSMISSION LINE
STEAM PLANT
HYDRAULIC FLANT
STEAM FLANT
FIXED CHARGES:- MILLS PER KILOWATT-HOUR
OPERATING CHARGES:- MILLS PER KILOWATT-HOUR
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
20
40
60
80
LOAD: % MAXIMUM CAPACITY

FIG. 1

mercial reasons may prove to be more important. I think it will be found if we could take an ideal condition, such as the lighting of a large city, and get a load curve put before us, that we would probably not end by wanting all our power from a hydraulic plant. We would find it desirable to generate part of that power (and for many reasons) from a steam power plant. I have gone over that part of the subject very thoroughly, and agree that there is only one type of steam plant to consider, and that is the steam-turbine plant; that type can be modified so as to cut the investment charges in two. I will refer to a few curves which I think will bring out the fact that in considering

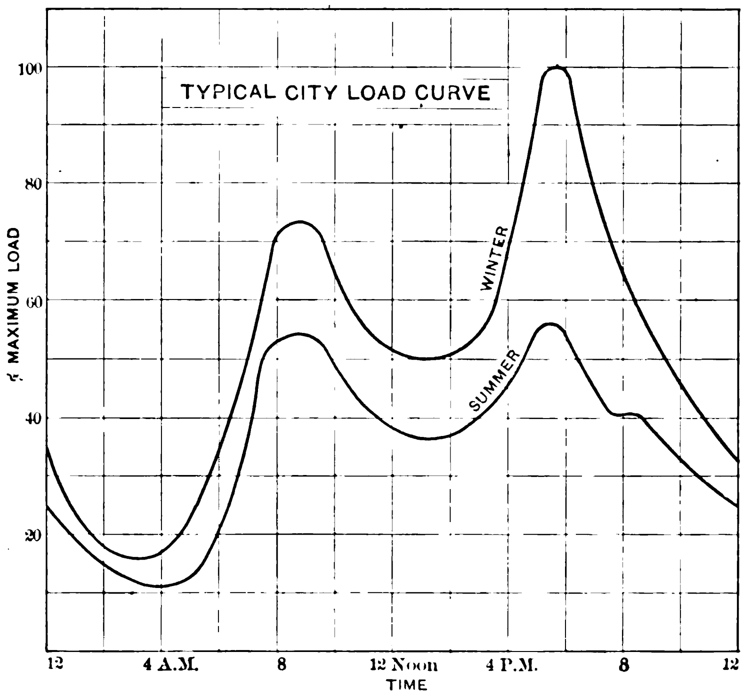

FIG. 2

a reserve plant, there is only one problem we have in hand —the fixed charges. The operating charges are almost negligible as compared to the fixed charges.

Mr. Doherty referred to the efficiency of boilers. The question before us is how the reserve plant shall be operated as a reserve on the hydraulic plant? The suggestion is here made that powdered fuel should be used, but no furnace has been found so far that will stand powdered fuel. The heat generated is so intense that no brick work can stand it. The other alternative to holding the steam plant in reserve, is to operate it every

day during peak loads. That is another point I will show in these curves. In order to bring something definite before you, I built up a load curve which may be representative of any

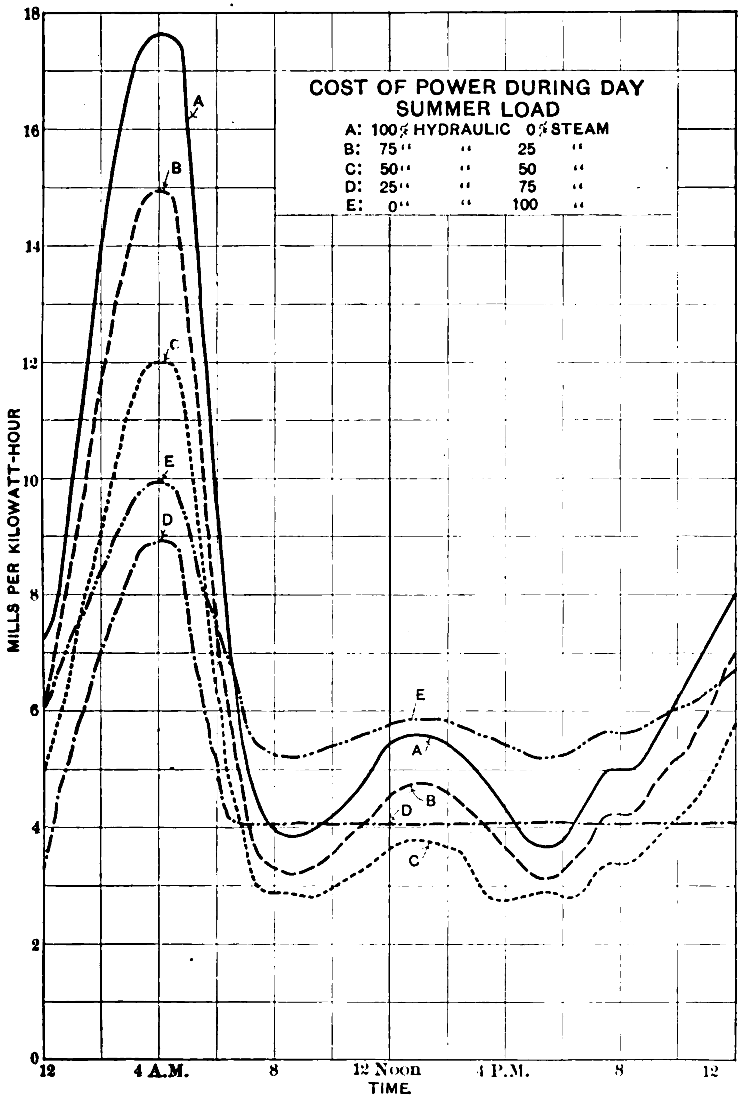

FIG. 3

large city: it is made up of a lighting load, a railroad load, and industrial-power load. In making these curves and calculations it has been necessary to make a number of assumptions. I

cannot think in arbitrary units, as Mr. Doherty has done, so have used dollars and cents, and have therefore assumed certain costs.

Fig. 2 is a load curve which is typical of that obtained in our large cities, the lower curve being the summer load, and the upper being the winter load. These are both shown, and for a

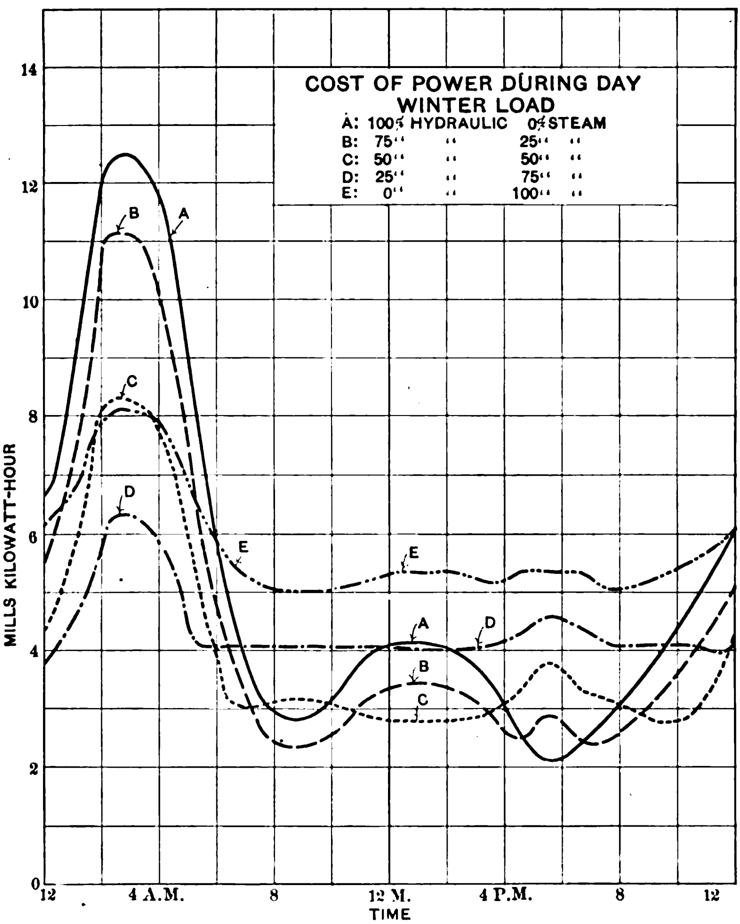

FIG. 4

good reason. I have taken the ordinary hydraulic plant and assumed a cost of $100 per kilowatt, and $55 per kilowatt for a double transmission line of 100 miles. That makes a total investment per kilowatt of power delivered, including the step-up and step-down transformers, of $155. The total fixed charges are assumed to be 11 per cent on the plant and 10 per cent on

the transmission line, annually. You will notice that the steam plant investment is $40 per kilowatt. That cost was arrived at in this way: a first-class steam-turbine plant will cost in the neighborhood of $80 per kilowatt. Supposing we order a 5,000-kw.

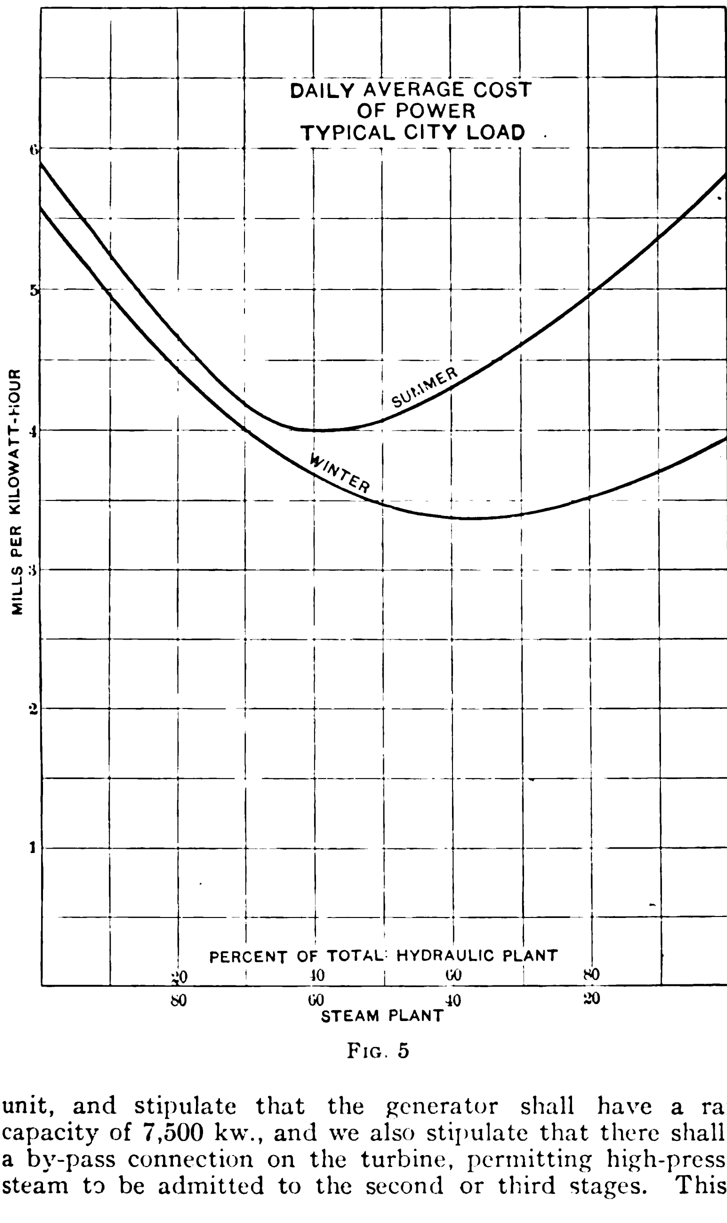

FIG. 5

unit, and stipulate that the generator shall have a rated capacity of 7,500 kw., and we also stipulate that there shall be a by-pass connection on the turbine, permitting high-pressure steam to be admitted to the second or third stages. This at

once enables us to generate 100 per cent above the rating of the plant during peak loads, at a very small reduction of efficiency. The boilers should have a ratio of grate area to heating surface of 1 to 30, thus enabling us to drive them at 200 per cent of rating when necessary. The fixed charges at 10 per cent load-factor on the steam plant are 5 mills, whereas on the hydraulic plant and transmission line they are 15 mills.

Fig. 3 represents the results obtained from a combination of hydraulic and steam plants as applied to the summer load curve in Fig. 2. The curve *A* is a hydraulic plant. The costs shown are not operating and maintenance costs alone, but also fixed charges; in other words, they represent the sum of the ordinates in Fig 1. The total costs between 1 a.m. and 6 a.m. are very high, due to the fixed charges, as shown in Fig. 1. The hydraulic plant at no point of the load curve is the best. Curve *B* is 75 per cent hydraulic and 25 per cent steam. That you will notice is also practically all the way above the others, the lowest average cost being reached in curve *C*, which is 50 per cent steam and 50 per cent hydraulic. It is, of course, impossible to generalize from these statements, as I have had to assume certain fixed conditions, and every load curve must be studied by itself.

I do not wish to say that this is a general solution of the power question. but it simply illustrates how it can be solved in one particular type of load curve.

Fig. 4 gives the series of curves for winter. Here you find that the conditions have changed, for the one giving the best average is not curve *C*, 50 per cent of each, but is now *B*, 75 per cent hydraulic and 25 per cent steam, and illustrates very clearly how these proportions vary at different times of the day. Not only the load-factor, but what might be called the diversity-factor should be considered; that is, the time and the shape of the load curve.

Fig. 5 is practically a summary of the other curves and shows, when applied to these two particular load curves for summer and winter, which combination gives the best average results. These curves clearly illustrate the average cost of power with different combinations of hydraulic and steam. The best combination for winter is 60 per cent hydraulic and 40 per cent steam. In the summer curve we find that 40 per cent hydraulic and 60 per cent steam gives the best results.

S. E. Doane: Bacon, in his oft-quoted essay on Studies says:

> Crafty men condemn studies, simple men admire them, and wise men use them: but that is a wisdom without them, and above them, won by observation.

Of any piece of composition, all the world asks three things, though the sequence of inquiry may vary.

The world of literature asks:

1. How is it said?
2. What does it say?
3. Who says it?

The world of science asks:
1. What does it say?
2. Who says it?
3. How is it said?

The world of commerce asks:
1. Who says it?
2. What does it say?
3. How is it said?

It is rarely that a paper is of importance to all three worlds, or to any one world for all three reasons. But I think we must concede that Mr. Doherty's paper is of the greatest value to the scientific and to the commercial worlds, each from their own separate viewpoints.

Of the making of many books and the writing of many papers there is indeed no end. An impractical dreamer might have said much that Mr. Doherty says, witness for illustration the wonderful dreams of Jules Vernes which science has been verifying so completely in these later years.

We are all deeply indebted to Mr. Doherty not only for what he has said but also because his recognized right to speak with authority makes what he says very valuable.

The members of the Institute will each appreciate the value of this paper. It can be expected, judging from the history of such papers that there will not be the evidence in the discussion of the value which each member places upon it as we are not wont to favorably express ourselves with particular freedom. It seems to me in this present case that this Institute owes a debt to its associates, who have been connected with unfortunate hydroelectric experiences, by which the commercial world has judged them, which it can best pay by a rather more free expression of opinion than is our wont.

The discussional tone of Mr. Doherty's paper tends to conceal or render less conspicuous many of the statements he makes. In a paper on "Rates" read before the National Electric Light Association in 1900, Mr. Doherty advocated a single service charge made up of two charges for two classes of service, as well as another charge for each kilowatt-hour. The purpose sought was to make the cost to the consumer depend upon the cost of supplying such consumer.

To his advice I think we will now universally agree, although there is some discussion as to whether the embodiment of this theory in the particular system he described is one which will be universally adopted, if any one system can be universally adopted. We should remember that Mr. Doherty's paper particularly disclaimed any advocacy of any universal system of rates, but that he did advocate the universal application of a principle. Recalling the discussion occurring at that time, it seems to me it was very largely overlooked that the paper really was in support of a theory and the embodiment of the theory in some comprehensive system was advocated on the ground

that if it was right then there was nothing to lose and everything to gain at some later time, when the inevitable improvement in efficiency of incandescent electric lamps would find many systems of rates insufficient to meet the changed conditions. In other words, Mr. Doherty advocated that even though the weather were fair we should embark in a ship that could weather a storm. Since the introduction of the tungsten lamp many engineers have recalled his position on this matter.

Mr. Doherty speaks specifically of the effect of increase in efficiency of heat engines upon the value of hydroelectric plants. In round numbers let us say that the highest practical efficiency from the coal pile to the steam-driven fly-wheel is now about 10 per cent, and that for a gas engine the efficiency is about 20 per cent. This leaves a wide margin for improvement, and is a situation similar to that existing in the lighting industry at the time of his paper on rates.

His qualifications of the value of hydroelectric plants due to the possibility of increased efficiency of heat engines is most interesting. Mr. Doherty may only see possibilities for improvement, but it is a fair question to inquire specifically if he has any knowledge of any work of this character of special significance at this time.

He points out that every undeveloped water power represents a constant source of unnecessary fuel consumption. He testifies to the importance of the movement to conserve our natural resources. He states, further, that in this movement the most important feature is the conservation of our various fuel supplies. These statements are made in a simple and commonplace style, but their importance is worth serious attention. We can replant our forests—there is an enormous margin of increase possible to the fertility of our soil—but already certain districts have found their fuel supply exhausted and other districts face fuel famine in the immediate future. The mild language used in stating the importance of the speedy development of our water powers as a means of conserving our natural resources is entirely inadequate.

I do not pretend to see this problem more adequately than the author of this paper, but I regret that he did not confine his whole paper to this single subject. There is much of value and importance in this paper under other subjects, but there is no discrimination between the knowledge imparted which is of great importance and that which is of only minor importance.

Had the author cared to, he could have pointed out that nitrogen is the important element in maintaining the fertility of the soil, and that at present we largely depend upon our coal to supply this nitrogen. The coal burned under our boilers yields no nitrogen for fertilization, while the coal distilled for gas-making, and the coal carbonized for coke in modern ovens, yields appreciable amounts of nitrogen in the form of ammonia. So the fuel saved by the development of water powers means

not only a direct fuel-saving but also the conservation of the material from which fertilizer may be produced. Few people to-day look upon our coal beds as immense deposits of fertilizer. Aside from our beds of natural fertilizing material, we depend almost entirely upon the nitrogen of our coals. Another method of nitrogenous production in form for fertilization is by means of electricity. The known processes for the fixation of nitrogen for the purpose of fertilization depend upon a production of power at a cost far below that price realized by the use of heat engines. This means the utilization of cheap water powers.

The products now used are either difficult of transportation or are bulky and mean much weight and much expense for freight transportation. The author has already pointed out that electricity may be transported to other localities at a lesser investment cost and with greater economy for irrigation purposes than for any other purpose. He might have pointed out that power could be generated at one point and transmitted to a point many miles distant for the creation of fertilization products at their point of application, thus necessitating the transportation of only one element of the product necessary for fertilization—transporting this by means of electric energy at a much less cost than matter which is acted upon by gravity can be transported by the usual means.

Mr. Doherty speaks of the failure to realize the predictions made by the investigating engineers in construction of hydroelectric properties and a reader might be led to believe that the investigating engineer is entirely to blame. This is certainly not always the case. Many of these disappointments have been due to mismanagement and tardy action on the part of others. The investigating engineer can only say what can be done, assuming reasonably competent management in every branch of the undertaking. In permitting his readers to believe that the investigating engineer is solely to blame, Mr. Doherty has in this one instance done a grave injustice to his erstwhile professional associates. I venture to maintain that even with the same investigating engineers, and no difference in the original report, few of these disappointments would have been realized had the execution of the entire enterprise been in the hands of any experienced and competent organization. Without wish to shirk responsibility, it is the duty of the engineer to place the blame where it belongs. It is an easy matter, but often unfair, to place the blame upon the investigating engineer. Were I doing this class of work, I should qualify my report by saying that I was unwilling to take the responsibility for the results promised, unless the financial, legal, organization, construction, contracting, and operation work were placed—if possible without divided authority—in the hands of people considered competent by me.

Strained financial ability, inexperienced direction, inharmonious relations between the various financial interests, unreliable

contractors, incompetent construction superintendence, ignorant management of market development, ill-considered changes from original plans, and incomplete operation of the plant after completion—all have played an important part in the disappointments which have been realized. How unjust it is to blame the investigating engineer for the incompetency of every element which enters into the various divisions which go to make up the sum of the successful going plant, starting with simply a prospective stream development!

Financial means sufficient to control a corporation does not insure competency in any of these numerous branches. Mr. Doherty can well say that the proper investigation of a water power proposition is an expensive matter; and he might have added that the ordinary promotion house is loathe to spend its own funds beyond the extent required for writing an attractive prospectus.

Mr. Doherty says that the less known about a prospective development the greater attractiveness can be given to the enterprise, and he further states that "we are apt to have the condition that only the poorer projects will be developed." I do not deny the correctness of this statement, but why speak of it wholly in the future tense? Is this not in a large measure the condition which has existed for at least the past three years?

If my remarks are seemingly a criticism of Mr. Doherty's statements, or his method of statement, it will be a matter of much regret to me. His statement of the relative increased valuations of quasi-public and other properties, in his presidential address before the Northwestern Electrical Association in 1899, his paper on "Rates" at the Chicago Convention of the National Electric Light Association, his extension and amplification of Thomson's Law for determining the selection of transformers, his work on the proper selection of lamp efficiencies, have all been stated in a manner which made little impression at the time, but appear of vast importance in looking back over the several intervening years. I venture the opinion that his paper on "Organization", read at the Chicago Convention of the National Electric Light Association in 1908, and this present paper, either for their contents or their results, will ten years from now seem of much greater importance than they do now.

Mr. Doherty speaks of the retardation of electrical development owing to the confusion of methods of charging for current and misunderstanding of terms. This point is of sufficient importance to be worth consideration, but it seems to me the importance of this matter is almost completely eclipsed by the bad effects resulting from the use of systems of charging which are both irrational and inequitable.

All electric energy supply companies are furnishing not simply energy but service as well. The expense to provide service to each consumer bears no universal relation to the energy furnished to each consumer. To charge purely upon

the basis of the energy supplied, without regard to the service supplied, or vice versa, means inability completely to develop the profitable market, and results in unjust inequalities between consumers and an aggregate charge for electrical employment beyond that which would be necessary if a rational system of charging was used.

No one can successfully deny that even within the profession an unwarranted difference of opinion exists regarding rates. This, therefore, seems to me to be a proper subject for comprehensive treatment by this Institute. The reference to rates and methods of charging in Mr Doherty's paper makes this a suitable time to consider the advisability of appointing a committee to handle this subject in much the same way as the High-Tension Transmission Committee has handled their subject. It is difficult for me to refrain from entering upon a discussion of this subject, but the time is too limited to do more than urge its complete treatment at some future time.

Under the heading of "Methods to insure against interruptions or to lessen the harmful effects of interruptions" Mr. Doherty speaks of rotating a steam or water turbine at full speed by using the generator as a motor, with a governor which will operate by a drop in voltage or frequency, opening the steam or water valve and immediately placing the unit in service as a generator. The expense for this will partly offset by the use that could be made of the generator under such conditions to regulate the power-factor of the system. So far as I know this has never been done. I am endeavoring to emphasize this suggestion so it will not be overlooked if it has merit.

Under the next heading there is much that seems to have deserved more extended treatment. The suggestion that we do not know as much about boilers as we should is probably true. More knowledge is needed regarding not only their efficiency from no load to maximum load but also the maintenance of this initial efficiency.

The suggestion regarding the ultimate capacity of boilers and the various features which fix the limit should not be allowed to drop without further discussion, either by the author or other members of extended experience in boiler work. I cannot concur in the belief that the Scotch type of boiler promises greatest economy for this work. It seems to me its relative large water-content would alone be a serious objection. My opposition on this point to the views expressed in the paper are prompted solely by a desire to bring out the reasons behind this statement.

The writer refers to the starting of boilers by the use of oil as an auxiliary to coal-firing. Natural gas is not infrequently used where natural gas and coal equipment are used somewhat indiscriminately for firing, but I did not know that natural gas or oil were ever installed deliberately for the purpose the author suggests. If this method is in use and is not a new suggestion

it would have benefited many readers had some examples or some literature on the subject been cited. The suggested use of powdered coal is also valuable, but it is open to the same comment; namely, that additional information would have greatly benefited the readers of this paper. My present information prompts me to say that except for cement burning, powdered coal is rarely used, and while we have the author's statement that " it is ideal for the class of service under consideration " and are willing to accept his opinion, yet we would appreciate his opinion as to how to study the problem to determine whether we can adopt it.

The method of " insurance against interruptions " is certainly both ingenuous and novel. It would not be difficult for any reader to identify the inventor of this method. Whether this method is generally applicable or not I am not competent to say. It seems to me that the time of day or night when the interruption occurs is a factor that should be considered in fixing the time of running the steam plant to insure against future interruptions. I do not consider myself competent to add any information of value to this subject, but I do think that lack of knowledge on this point, and lack of knowledge regarding rates and the factors which go to make up the cost and value of service, has prevented many supply companies from selling their service and many prospective purchasers from availing themselves of a service advantageous to them. Simply the inability of the purchaser and seller to understand how to buy and sell has played an important part in the retardation of electrical development. Not only this, but it has probably been the foundation for unnecessary competition.

It seems to me that Mr. Doherty touches upon a fundamental reason for the slow development of a market which will apply not only to the case of hydroelectric plants, but more widely and with just as great force to all central station work. The public must be made to understand the value of cost of service as well as the value of the electrical energy. Illogical and unjust method of charging have served greatly to retard the fullest and most complete utilization of the capital invested in central station securities. As Mr. Doherty says, the fault in this matter lies to some extent with the electrical fraternity itself which it seems has not yet fully realized the importance of this question, so vital to the commercial success of its efforts. The engineer may make the physical plant as perfect from the purely engineering standpoint as anything on this world of ours can be. With this task complete, however, his duty is not done. He must do all he can to enable the plant to be used to the greatest advantage, and in doing so must become commercial enough to apply his engineering principles to the construction of a rate system which must not only be equitable but which will allow the greatest opportunity for future healthful development. The engineers and commercial men must work together. Engi-

neering dictates must be accepted by the commercial man as the basis of operation. He must build on a solid foundation, otherwise his commercial structure will probably be seriously injured by some future and perhaps unforeseen development.

Systematic and logical cost-keeping methods have served to demonstrate that there are some principles of rate-making which cannot be disputed. A few years ago the idea of embodying them in a rate system was scoffed at. Some stations, however, with sufficient faith in their convictions, have demonstrated the entire feasibility of such procedure with satisfaction to their customers and profit to themselves. The complicated nature of the cost of the production of electrical energy and the comparatively slow progress in its understanding, should be a challenge to the Institute to investigate and establish correct principles, thereby placing the entire matter of rates upon a sound and logical basis. I think that this Institute should be a forum for the consideration and solution of such problems. These comments are prompted by the belief that the importance of proper methods of paying for or insuring against interruptions of service, together with a better understanding of matters pertaining to the method and rate of charge and the value of service, are not properly recognized. It seems to me that the method of insurance proposed by Mr. Doherty would be very expensive; for this reason I should like to see specific figures of the cost of this method.

That the investment and maintenance cost for meters alone for large groups of central station consumers is greater than the investment and maintenance cost of the generating equipment needed for their supply is a startling but probably true statement. It illustrates the fact that we are furnishing an expensive service entirely aside from the energy supplied. This fact also seems to sustain the position taken by Mr. Doherty in his paper entitled "Equitable, Uniform and Competitive Rates", in which he maintained that a uniform charge to each customer in addition to the capacity and energy charge was essential if equity were to be maintained as between all consumers.

In illustrating the usual characteristic difference between the elements of the cost of supply for a steam plant in comparison with a hydroelectric plant, Mr. Doherty's method is, I think, a valuable addition to the proper understanding of the problem. Under usual conditions there will always be some certain load-factor where the total costs are equal.

Mr. Doherty speaks of the need of maximum development of a stream in relation to the conservation of our natural resources. He also speaks of the advisability of giving hydroelectric companies the right of condemnation. It is hard to see how the maximum development of a stream can be secured without the right of condemnation, although this right alone will not insure the result which is sought. It seems to me that Mr.

Doherty's position regarding the right of condemnation must be conceded by all as correct.

This brings us to the question of " how can maximum stream development be assured, even given the right of condemnation." It is an easy matter to see how hasty or unintelligent planning may bring about developments at the wrong locations, or of a character that will permanently limit the power yielded by the stream to a small fraction of the total power available.

It is also easy to see how inadequacy of funds may necessitate a 30-ft. development at the wrong location while a 100-ft. development was possible at the right location. It is also easy to see how this inadequacy of funds may forbid the purchase of land for reservoirs which would enable the flood waters to be stored and used for power purposes. I have no adequate solution to offer to this problem, and can only make one minor suggestion. It occurs to me, however, that by restating this problem it would perhaps insure not only greater interest in the solution of the problem but would also call the attention of a greater number of people to the problem. The obvious suggestion is that complete surveys of every stream capable of yielding power be undertaken by the Federal or State Governments, and that these surveys be directed to determining the nature of the development necessary to secure the maximum power from each stream. Since many states have spent large sums of money in their geological surveys, to locate coal, clay, cement rock, and other natural resources, it does not seem unreasonable for these same states to investigate their streams as a means of conserving their natural resources.

There remains now but one more point; namely, the maximum hydraulic development which commercial economy will warrant. When Mr. Doherty says that this development can be increased until the available water will permit some of the generating units to be used but four days in the year, it cannot be designated as other than a startling statement. It is so contrary to general methods now in vogue that it should not be allowed to stand without discussion as to its accuracy. Mr. Doherty gives an example in which the cost for steam power is cheaper for any load-factor less than 38 per cent, and then he says that " the operation of a water turbine for 100 hours per year will, in some cases, warrant its installation ". It will be noted that 100 hours would represent a load-factor of only 1.14 per cent while the example given represents a use of equipment for 3328 hours, or 33 times as long.

I do not assume that the author of the paper is in error, in fact I believe he is right, but I do think that these two statements will seem contradictory or confusing to some of his readers unless further explanation is made. No doubt Mr. Doherty has long ago formulated some law for the determination of the maximum power which can be developed with commercial economy, and the statement of this law by him would add much to the value of the information contained in his paper.

I wish to give a word of explanation regarding my reason for presenting such a lengthy discussion. It is simply this—a paper merely presented before an engineering society is very often read in a cursory manner without the careful study it deserves. If the discussion serves to bring out various views upon the important principles involved it not only makes us think more carefully about what the author has said but it shows us new ways of looking at a subject that may at least be interesting.

Those of us who are interested in central station work have learned that what Mr. Doherty says, or writes deserves careful study, and I hope that by touching upon the points in his paper which seem of the most importance to me I may have helped to concentrate the interest of the reader upon them and perhaps caused thereby a second and more careful reading of the original article.

Cary T. Hutchinson: Mr. Doherty's paper offers a number of opportunities for comment, among them the matter of depreciation of hydroelectric plants. This is probably one of the most important matters touched on, and there is comparatively little regarding it in the literature of engineering.

Much data have been made public recently concerning depreciation of steam generating plants by the various public authorities, particularly the public service and railroad commissions, and the testimony of well known engineers is accessible. There seems to be a general consensus of opinion that the depreciation from " wear and tear " of a steam electric generating plant will vary from 5 to 7.5 per cent, and that in addition to this there is an entirely independent depreciation due to " obsolescence "; this also is put at from 5 to 7.5 per cent.

The heavy depreciation on such plants is due to the fact that all the machinery used is subject to very great wear and tear, and further that the type of steam generating plants changes rapidly. One has to go back only a few years to recall the gradual progression from small high- and low-speed engines belted to generators, to high- and low-speed engines direct connected; then to the marine type of engine, either compound, triple, or quadruple expansion direct-connected to generators —finishing with the most advanced type of reciprocating engines, as seen for instance in the Interborough plant in New York. But we all know that this type of plant is now considered in great part obsolete, and that new plants are building almost exclusively with steam-turbines in very large units, such as shown by the new Waterside plant in New York and the Quarry Street plant in Chicago. It is probably safe to say that the average life of any type of steam generating apparatus has been less than 10 years, although of course many plants have been in operation for a longer period of time. New York affords an excellent instance of obsolescence; it was only 25 years ago that the old Pearl Street Station of the Edison Company began

operation. Since then that company has built and abandoned at least four distinct types of station, and would probably now consider as obsolescent the Waterside No. 1 completed only eight years ago.

Nor is there much reason to think that the end of this period of change has been reached. There is in sight the development of the internal combustion engine, the possibility of gas-turbines, and, for all we can say, of other means of converting the energy of coal into mechanical energy, which at present have not even been suggested. The fundamental reason for this is found in the very low efficiency of the process of converting the heat energy of coal into mechanical energy, 12 per cent being about the best figure for steam plants and, say, 25 per cent for gas-engine plants. There is obviously a wide margin between these figures and the best that may be imagined, and on this account a liberal allowance must always be made for depreciation due to obsolescence of plants of this kind.

With a modern hydroelectric generating station the matter is quite different: first, because the kind of construction is much less subject to depreciation through wear and tear; secondly, because the efficiency of conversion is much higher, and therefore there is not the wide margin for improvements. The efficiency of conversion in a modern hydroelectric plant from the theoretical energy of the water to the output at the bus-bars of the power house will be about 75 per cent, leaving a theoretical margin of only 25 per cent for all improvements. The efficiency of large electric generators and transformers is so high that there is no reason ever to expect material improvement in this direction; probably the cost of such betterment would exceed the advantages to be derived. There remains only the efficiency of the water wheels, and although this will undoubtedly be increased from the conventional figure of 80 per cent to 90 per cent, possibly this improvement would result in an increased output of only about 10 per cent, whereas with the steam plant the theoretical improvement may be put at from 200 per cent to 500 per cent.

The history of existing water power plants, as at Lowell, Lawrence, and other places, shows that they have a good long life; they are relatively stable in comparison with steam plants. These facts and consideration of the character of the machinery leads to the conclusion that depreciation due to "obsolescence" in a modern hydroelectric plant will be small.

An analysis of the depreciation of such a plant is given in Tables I and II. Table I covers the cost of construction of a modern, medium head, hydroelectric plant of large capacity, delivering energy at comparatively short distances in large blocks. While this table does not pretend to be exact for any one plant, yet I believe it to be fairly typical of construction of this character. It of course does not apply to the high-head plants in the West with flumes or ditches or steel pipe lines.

TABLE I

Cost of modern medium head hydroelectric generating and transmission plant	
Item	Proportional cost
1. Riparian rights for dam and flowage basin, real estate, franchises, organization expenses, preliminary legal expenses, cost of financing, removal of railroads, highways, bridges, and all expenses preliminary to actual construction work	20
2. Permanent construction, dam, power house, and waterways, etc.	30
3. Equipment of power house	14
4. Transmission system	13
a. Right-of-way . . . 4.50	
b. Copper . . . 1.50	
c. All else . . . 7.00	
Sum	77
5. General expense, engineering, administration, legal, etc.	11
6. Interest during construction	12
Total	100

Item I of Table I covers the many costs that must be met, exclusive of the actual construction costs. Item 2 is principally made up of rock excavation and concrete. Item 3 is for the usual equipment, comprising water wheels, generators, switchboard apparatus, transformers, and the various small parts of the power-house equipment. Item 4 covers the transmission system, including sub-stations. Items 5 and 6 are self-explanatory. Of these items only 2, 3, and 4, comprising in all 57 per cent of the total, are subject to depreciation; and of these the greater portion of Item 2 is not subject to depreciation, as it covers rock excavation and concrete almost entirely.

Table II gives an estimate of the depreciation of the plant based on the cost given in Table I.

TABLE II

Depreciation of system			
Items of Table I	Proportional cost	Assumed life	Annual amount for depreciation, in per cent of total cost
1	20%		—
2	30	50	0.168
3	14	20	0.458
4	13	20	0.415
5	11	—	—
6	12	—	—
			1.041%
Equivalent to an average life of about 39 years.			

This table is calculated on the basis of the assumed life given for the different parts of the plant, the annual charges being compounded at the rate of 4.5 per cent.

Table III shows in detail the proportional parts of the total cost of the various elements going to make up Items 3 of Table I, and the life assumed for the different parts, together with the annual depreciation. This gives the total annual depreciation charge of 3.4 per cent, making the equivalent life of the power house as a whole 19 years; in Table II this is taken at 20 years.

TABLE III

Depreciation of equipment of power house

Item	Proportional cost	Life years	Annual amount for depreciation in per cent of total cost
1. Stop logs, gates, and other wood exposed to air and water	0.80	5	0.146
2. Flooring, roofing and hardware, and miscellaneous fixtures	9.80	15	0.472
3. Tile wainscoting, sewage, plumbing system, and metal window frames, etc	2.45	15	0.118
4. Electric light and telephone	0.80	10	0.065
5. Switchboard equipment	4.35	10	0.355
6. Cables and heavy wiring	3.90	10	0.318
7. Cranes	1.25	15	0.060
8. Water wheels	33.75	25	0.757
9 Water-wheel governors	2.90	10	0.235
10. Generators and transformers	40.00	25	0.898
	100.00		3.423

3.423%—Equivalent to average life of 19 years

Tables IV and V show similarly the details of the cost of the transmission line, and of the sub-stations which taken together make up Item 4 of Table I. The equivalent life of the transmission line is 26 years and of the sub-station 20 years. In Table II both are taken at 20 years.

The reason for the low depreciation on the transmission line is the comparatively high cost of the right-of-way, 45 per cent of the total. This together with nearly 25 per cent for copper makes the depreciation on the whole system low. The total depreciation due to wear and tear on a hydroelectric system of this character may then be placed at approximately 1 per cent, equivalent as a whole to a life of about 39 years, approximately the life of the bonds usually issued for the construction of plants of this character.

TABLE IV

Depreciation of transmission line			
Item	Proportional Cost	Life years	Annual Amount for depreciation in per cent of total cost
1. Right of way	45.	—	—
2. Towers	18.4	15	0.885
3. Special structures	5.1	10	0.415
4. Insulators	2.1	10	0.170
5. Copper	23.7	25	0.530
6. Installation	5.7	—	—
	100.0		2.000
Equivalent to about 26 years life			

TABLE V

Depreciation of sub station			
Item	Proportional cost	Life years	Annual amount for depreciation in per cent of total cost
1. Land	6.0	—	—
2. Buildings	30.	25	0.67
3. Transformers	40	20	1.28
4. Switches, etc	16	10	1.29
5. Installation	8.	—	—
	100.		3.24
Equivalent to 20 years			

It is difficult to see why in plants of this character there should be any charge for obsolescence; once in operation there is no sufficient inducement to change the principal features of its construction; in fact, these features cannot well be changed, as they are fixed in the original design. It is understood that switching apparatus may change, transformers, may change to some extent, and the minor appliances change, but the depreciation charge for wear and tear should cover all these features. The water wheels can only become antiquated by the introduction of some-

thing very much better, and the possibilities are not great. With these facts in mind, I believe that an additional depreciation charge of 1.5 per cent for obsolescence is certainly a very liberal estimate.

The fixed charges on the two classes of plants can then be taken somewhat approximately as given in Table VI.

TABLE VI

Fixed charges of steam and water-power generating plants

	Steam	Water
Interest	6.00%	6.00%
Insurance	0.50	——
Taxes	0.50	0.50
Depreciation	5.00	1.00
Obsolescence	5.00	1.50
	17.00%	9.00%

The total annual charge on a steam plant will be about 17 per cent, and on a water-power plant of the character under consideration about 9 per cent on the investment; if the investment were even approximately equal, the water-power plant would be able to deliver energy at a much lower price than the steam plant, but this is far from the case. A modern steam-turbine plant of large size can be built for \$80 per kilowatt of rated turbine capacity. There are very few hydroelectric plants that have cost as little as \$150 per kilowatt of rated capacity; generally the cost will run up from \$200 to \$300 per kilowatt of power delivered at the sub-station bus-bars, including all costs of the generating and transmitting system. For the purpose of determining the relative cost of energy supply by the two systems, \$200 per kilowatt of delivered power will be a fair price for the hydroelectric plant, rather favorable than otherwise. The operating cost of the steam plant may be taken at say 0.5 cents per kilowatt-hour and of the hydroelectric plant at \$2 per kilowatt per year of plant capacity, irrespective of output. The annual charge on the steam plant then becomes \$13.60 per year and on the hydroelectric plant, including the operating cost, \$20.00.

Table VII based on these figures then gives the cost of energy for the two plants for various annual load-factors; the cost for the hydroelectric plant is seen to be much lower, under all conditions of practical operation.

It is, however, ordinarily not the cost but the selling price of the energy from a hydroelectric plant that has to be considered. Ordinarily a hydroelectric plant is built to supply a market already supplied by steam plants, and the hydroelectric company

is expected to sell to the steam company at a price less than the bare operating cost of the steam plant, the argument being that the operating company would have to carry fixed charges on its steam plant whether or not it is operating. The hydroelectric plant at the same time is expected to make a profit. Taking this profit at 6 per cent on the investment, or $12 per kilowatt of plant capacity, Table VIII shows the selling price the hydroelectric plant must obtain for various load-factors.

TABLE VII

Cost of energy per kilowatt-hour at various annual load-factors

Basis: $13.60 plus 0.5 cents for steam plant
$20 for water plant

Load-factor	Steam plant	Water plant	Ratio water to steam
15	1.54 cents	1.52 cents	100%
25	1.12 "	0.91 "	82
33	0.97 "	0.69 "	72
40	0.89 "	0.57 "	65
50	0.81 "	0.46 "	57
60	0.76 "	0.38 "	51
75	0.71 "	0.31 "	43

TABLE VIII

Selling price of energy from water plant with 6% on the investment or $12 per annum added to cost for profit

Load-factor	Selling price
15%	2.44 cents
25	1.46 "
33	1.10 "
40	0.92 "
50	0.73 "
60	0.61 "
75	0.49 "

If the steam company is willing to pay as much as 0.5 cents per kilowatt-hour, it is evident that the hydroelectric plant can supply only a very small proportion of the load of the steam company; that is to say, that portion of the load having a load-factor of 75 per cent. If the steam plant expects to get energy at less than its own cost, the hydroelectric plant cannot possibly sell to it.

This analysis shows clearly the preponderating part that the charges on capital bear to the total cost in a plant of this kind. Of the total revenue of $32.00 per kilowatt per annum, forming the basis of Table VIII, no less than $24, equal to 75 per cent, is a direct charge on the investment. If this plant were built as a part of the general system by a corporation which could get its money at 5 per cent, the total annual cost would be reduced to $18.00 per kilowatt per annum, and the selling price for energy at a 50 per cent load-factor would be 0.41 instead of 0.73 cents.

There are other important disadvantages that hydroelectric plants usually labor under; of these one of the most important is lack of flexibility. The rating of such plants is usually fixed by the output of the turbines at 80 per cent gate opening. This leaves just sufficient margin for governing and possibly sufficient spare capacity to operate at its rating in case of one unit being disabled. A steam-turbine plant will, on the other hand, carry very heavy loads in excess of its rating, the exact amount varying with the conditions; but its overload rating can be taken conservatively at 50 per cent for one hour. Hence, if costs are estimated on the basis of the one-hour capacity of the steam turbine plant they will be materially less than given in Table VII: for a 50 per cent load-factor, for instance, the cost per kilowatt-hour would become 0.58 cents instead of 0.81 cents, as given in the table; in other words, the cost would not be much greater than that of the hydroelectric plant.

That this point of view is correct is proved by several important contracts for the supply of steam energy recently executed, notably that of the Chicago Edison Company, with the Chicago Railways, in which the provisions for determining the maximum demand on which the charge of $15 per annum is based are such that no hydroelectric plant could possibly compete. The maximum demand in the case of a hydroelectric plant when selling to a big customer must be taken equal to the capacity of the machinery employed in supplying it, which is, practically speaking, the rated capacity. In other words, the maximum demand must be based on say the five-minute maximum, and little leeway can be allowed to the customer above the hard and fast maximum fixed by this consideration.

A further disadvantage that hydroelectric plants labor under, which leads to a high cost of the supply, is the necessity of ensuring continuity, against interruptions of the supply due both to the low-water period that exists on practically all the rivers in the country, and to the possible failure of transmission lines. As Mr. Doherty points out, the only certain way to ensure this continuity is the establishment of a steam plant at the point of consumption. This steam plant may be owned either by the customer or by the hydroelectric company, depending upon the contract arrangements that can be made for its use. But whatever these may be, it means an additional burden

on the hydroelectric plant, which may amount to as much as \$5 or \$6 per kilowatt per annum in extreme cases, but which on the other hand may become as little as 0.75 cents to \$1 per kilowatt if favorable arrangements can be made.

A consideration of these various elements indicates, I think, the reason why so many hydroelectric plants have been total failures from the point of view of a financial operation. In a word, they are so burdened with capital charges and costs that do not enter directly into the productive capacity of the plant, that competition with a modern steam plant is in many cases rendered impossible. The remedy would seem to be a total change in the methods of financing such propositions, by which they will be handled in the same way as the construction of a railroad or the establishment of a steel mill, or any other commercial enterprise.

H. W. Buck: Mr. Doherty has brought up one important matter, and that is the attitude of the Federal Government toward water-power development. I think that this Institute can do much toward educating the popular mind in this regard. There has been a great deal of literature circulated during the past year which has given false impressions about the fabulous value of water powers as they exist in nature. As a matter of fact, a mountain stream in the wilderness has practically no value whatever in itself. It is only when it is combined with a very large expenditure of money, ranging perhaps from \$100 to \$200 per horse power, together with the expenditure of a great deal of brain power in management, financing, and engineering, that this natural geographical situation, called a water power, derives a value. This value is contributed to only in a small degree by the water in its natural state. In this respect the people have a false idea about the value of those properties which the Government has lately refused to give over to private enterprise for development.

Furthermore, when a water power is developed and is successful, it is profitable only in a reasonable degree. At the present time active competition exists between water power and power from various forms of heat engine, and this condition is likely to continue for many years. Even good water powers cannot compete with power generated from steam at low load-factor in parts of the country where coal costs less than, say, \$2.00 per ton. People have been led to believe that a water power is an absolute power monopoly, but such we all know is far from the fact. The Government also apparently assumes that water powers will, for all time, continue to be the only source of power. This hardly seems to be justified. The most efficient heat engine to-day has perhaps a commercial efficiency of 20 per cent, and there is therefore a large margin for possible improvement and economy in this form of engine. A slight improvement would still further increase competition with water power. Furthermore, the energy of water power is merely

converted energy of the sum. It is quite possible that other means for the utilization of the sun's energy may develop in future generations. The attention of the Government is directed toward the preservation of water powers for the sake of posterity. It may be that when posterity arrives the energy of water powers will not be required at all, other sources of energy having superseded its use; and in the meantime the prevention of water power development represents a sacrifice for present generations and the loss of a great industrial opportunity.

The Government also seems to have adopted a discriminating attitude against water powers as distinguished from other natural resources. Economically there is no difference between a water power and any other form of natural resource. It is a situation in nature which can be developed for reasonable profit. So can timber lands, mines, farm lands, and all other property be developed and their potential value liberated for the benefit of mankind; but the agitation against the private development of water power as the one natural and injurious monopoly, without reference to all other forms of natural resources, seems to be a very one-sided form of socialism and an unjust discrimination against those who are interested in the development of water power.

This Institute can undoubtedly do a great deal toward correcting the wrong impressions which people have at the present time, with reference to the real situation respecting water powers and water-power development.

W. N. Ryerson: In speaking of collateral enterprises, Mr. Doherty says, rightly, that they should receive our careful attention. I have in mind one contract which provides that the customer is entitled to power generated by the water which would otherwise flow over the spillway of the hydroelectric plant. This contract is with an electrochemical company whose process enables them to reduce their consumption of power from time to time without serious interference; and the contract expressly provides that no interference shall take place with the continuous supply of power to other customers. Naturally, power is sold to this customer at a low rate, and a guaranteed minimum amount of power is provided, below which the customer cannot be asked to reduce his demand.

In saying

> Non-coincidence of maximum demands is, however, a legitimate source of profit to any supplying company, and this non-coincidence of maximum demands is generally a primary source of profit to the supplying company.

I take it Mr. Doherty does not mean that it is not legitimate for a supplying company to offer special rates for "off-peak" business, which I think every such company does.

The additional statement that,

> The capacity the consumer should pay for should generally be based upon this absolute maximum peak experienced at any period throughout the year.

Experience prompts me to say that I would prefer this should be based on the maximum peak during the term of his contract.

Mention has been made by various speakers of the subject of "Depreciation." In the state of Wisconsin there is a public service commission composed of able men, and not very long ago a certain town in the state, through its citizens, petitioned for a reduction in electric rates. The commission held hearings, and after finding that the company was not setting aside a depreciation fund, ordered it to raise its rates, in order that such a fund might be provided.

There is a recommendation in the paper that all terms of expression be standardized. I should like to see the term "load-factor" made more definite as to the time-interval covered by the maximum peak upon which it is determined.

Calvert Townley: I agree with the author of this paper that the Institute can perform a distinct service to the country at large by educating the public to a better understanding of the basic facts governing hydroelectric developments. Although my experience is limited, I can say that the more I operate and investigate water powers the greater respect I have for steam. It is unquestionably true that in New England there are comparatively few water powers than can be commercially considered for hydroelectric development, because they cannot compete with steam on the basis of cost. In the face of these facts, I am, naturally, reluctant to hear advocated the enactment of any laws by Federal or State governments which will put additional burdens on the present expense of developing or operating New England water powers. I believe that such development is of greater benefit to the communities supplied with power than it is to the capitalists who invest in the development itself, and that any additional burdens placed on such investment will tend to prevent all hydroelectric development wherever the margin of prospective profit is close, thus retarding by just that much the progress of any community which would have been served.

Compared with a steam-driven power station, a hydraulic plant is admittedly inferior in every particular except its cost of operation. Therefore, there must be a sufficient saving in such cost to warrant accepting other disabilities. The general public, and not a few engineers, seem to believe that because it does not consume fuel, water power costs nothing to produce. We seldom see the facts analyzed, but it may be interesting to inquire: what is the possible margin of saving in the total cost supplying power from water over the cost of performing similar service by steam?

Consider first the station itself. We see that it costs to operate a hydroelectric station about the same amount that it does to operate a modern steam-turbine station, omitting all boiler room expenses—fuel, boiler water, ash-handling, maintenance,

and repairs. The largest of these items is of course fuel. At a New England seaport a high grade of anthracite coal would average to cost about $3.00 per long ton, and, therefore, a fuel consumption of minimum 2.5 lb. to maximum 3.5 lb. per kilowatt-hour results in the corresponding fuel cost per kilowatt-hour of minimum 0.334c. to maximum 0.466c.

To translate these figures into annual costs we must next consider the load-factor. If the yearly output of a station equal an average continuous load of 20 per cent of its rated generator capacity there will be 1752 kw-hr. annual output for each kilowatt of machinery installed. Similarly, an average output of 40 per cent produces 3504 kw-hr. annually for each kilowatt installed. Multiplying these two sets of figures together, we see that with the minimum coal consumption and the lower load-factor, the annual fuel cost per rated generator kilowatt installed will be $5.85. With the maximum assumed coal consumption and the higher load-factor, this cost becomes $16.32. I have taken the load-factors of 20 per cent and 40 per cent for the reason that these factors are not far from the limits found in hydroelectric developments in New England; that is to say, it is unlikely that a station will produce annually more than 40 per cent of the theoretical possible output, assuming every unit to be operated 24 hours a day, 365 days a year, at full rated load, while it is quite possible that under any but favorable conditions a 20 per cent output may be the best obtainable. These assumed conditions are, therefore, not theoretical, but practical. They must be reckoned with.

The other boiler-room expenses—mainly labor and repairs—may be partly, wholly, or more than wholly offset in a hydraulic station by the repairs to hydraulic structures, reservoirs, flume, forebay, tail-race, etc., and also by the cost of patrolling and repairs to the transmission line. The wide variation between hydraulic structures, and between the length, type, and voltage of transmission lines, makes impossible any concrete comparison of these cost items. We have to admit, however, that not infrequently in a hydraulic plant the items named will annually equal or exceed those of the corresponding steam station, leaving the net annual operating margin in favor of the water power no more than the saving in fuel.

The next item of cost, and one which many of us would like to forget when we wish to develop a hydraulic property, is the fixed charge. Here is the worst stumbling block. The average flow of New England streams is 40 per cent of their maximum flow, omitting freshets, while the minimum flow in years like the current year, and last year, may almost reach the vanishing point. The engineer who undertakes to develop a water power is, therefore, confronted at the outset with the question: What per cent of this maximum flow shall I develop? If the development be for the minimum flow only, the cost per unit of capacity may, become, and probably will become, so abnormally

high as to be at once prohibitive. Per contra, if, in order to reduce the unit cost, a large percentage of the maximum flow be developed, it can all be used for but a part of each year, and a correspondingly large relay supplemental power must be provided. The usual decision is a compromise. Enough flow is developed to make the unit cost seem not too abnormal, and the disability of a shortage of water during, perhaps, two months of each year is accepted. During that time a relay steam plant must be operated. Many New England water powers cost to develop considerably more than would steam plants of equivalent rated capacities. In addition, transmission lines and relay steam plants of no inconsiderable size have to be paid for. It must not be forgotten, further, that whereas steam turbines are now commonly designed with large overload capacity, a water wheel has no overload capacity, and the rated capacity of a hydraulic development must, therefore, equal the peak load which it may be expected to carry. The ordinary commercial peak load is of such short duration that the overload capacity of a steam turbine is nearly as available as is the rated capacity; consequently the rated capacity of a steam plant may be from a quarter to a third less than that of the hydraulic station built to perform exactly the same service. The capacity and the cost of the hydraulic development must be further increased on account of the transmission losses, which reduces by just so much the power available at the point of utilization. Let me illustrate what I have said by applying some average conditions and working out a concrete case. Let us compare the total cost of producing current by water and by steam under the following conditions:

TABLE I

Hydraulic Development—5000 kw. capacity	
Cost of same, not including transmission lines	\$125 per kw.
Duplicate pole lines for transmitting power to point of utilization	\$50,000
Sub-stations at distributing points, capacity 4500 kw.; cost of sub-station	\$8.00 per kw.
Peak load at power station	4000 kw.
Average load the year round on station—that is, 30 per cent load-factor	1500 kw.
Average loss in line and sub-stations	10%
Minimum flow of water for two months	1000 kw.
Steam relay at distribution center, rated capacity with 50 per cent overload guarantee	2500 kw.
Cost of steam relay per kilowatt rated capacity	\$100
Annual labor and material cost to operate the hydraulic power station, sub-station and to maintain the property	\$25,000
Cost to operate steam relay plant and supply the insufficiency of power during two months, also to keep it on call for the remainder of the year	\$3,000
Interest, depreciation, taxes, etc., on total cost of hydraulic plant	10%

From these assumptions we at once deduce the following figures:

TABLE II

Capital Invested.	
5000 kw. at $125	$625,000
Pole line	50,000
Sub-station, 4500 kw. at $8.00	36,000
Steam relay, 2500 kw. at $100	250,000
Total investment	$961,000
Fixed charges, 10 per cent	$96,100
Operating and maintenance cost of hydraulic plant	25,000
Operating and maintenance cost of the steam plant	3,000
Total annual cost	$124,100

Output 1500 kw-hr. 24 hours per day, 365 days = 13,140,000 kw.; less 10 per cent loss in transmission = 11,826,000 kw-hr. net power delivered at point of utilization, making the cost per kilowatt-hour delivered—10.5 mills.

Had this power been produced by a steam turbine plant located at the point of utilization we may assume the following conditions:

TABLE III

Capacity steam plant, to deliver a peak load of 4500 kw., corresponding to that required for the hydraulic plant, less transmission losses, the steam plant to have an overload capacity of 50 per cent; that is, 6000 kw., or if four 1000 kw. units be selected, the overload capacity with one unit out of service will be 4500 kw., equivalent to the peak load. Cost of steam plant rated capacity	$100 per kilowatt
Coal consumption	3 lb. per kilowatt-hour output
Cost of coal	$3.00 per long ton
Labor and maintenance charges same as for the hydraulic plant	$25,000 per year
Fixed charges and depreciation, capital invested as against 10 per cent for the hydraulic plant	12 per cent

On the basis of these assumptions we at once deduce the following figures:

TABLE IV

Investment necessary.	
4,000 kw. at $100	$400,000
Fixed charges at 12 per cent	48,000
11,826,000 kw-hr., fuel cost	47,304
Other operation and maintenance charges	25,000
Total operating and fixed charges for the year	$120,304

or a cost per kilowatt-hour produced of 10.1 mills, slightly under that of the corresponding hydraulic cost.

It is clear from these figures that, although the operating cost of the hydraulic plant is very much lower than that of the steam plant, its fixed charges are so much higher that the saving is more than offset. Therefore, if its construction can be justified, a reasonably low cost of a hydraulic plant must be assured beyond any reasonable doubt, or a high load-factor must be secured, or both.

On these two points there is a vast amount of current misinformation. Not a few hydraulic projects, some of them very large ones, have put their investors badly "in the hole" because the enthusiasm of their promoters had underestimated the cost of their construction, and overestimated, very much overestimated, the average load to be secured.

I am operating a 6000-kw. water power which is developed for only 60 per cent of the 10 months' stream-flow instead of 100 per cent, as in the example taken, and it should, therefore, have a greater per cent of minimum flow to draw upon. This power is further supplemented by three steam relay plants. We apply all of the power generated to our own service, and we have a heavy demand for it. We are, therefore, able to operate under favorable load-factor conditions. Notwithstanding this fact, the best average annual load-factor I have been able to obtain is 38 per cent. The figure of $125 per kilowatt for hydraulic development is under the average estimated cost of those New England powers that have come under my own observation. Many powers would materially exceed this cost. The steam plant cost of $100 per kilowatt is a fair average cost, as most of you know, although it can be frequently lowered, as also can the coal consumption of 3 lb. used in my example. These conditions, then, are practical, present conditions, with which we are confronted; and in the case of which I have spoken no one would consider the installation of the hydraulic plant, because in addition to costing more to produce this power the possibility of interruption by ice, freshets, damage to the reservoirs or other hydraulic structures, breakdown of pole line, etc., render the service less desirable, and, consequently, add an additional element of expense.

It is doubtless, true that the nation's visible coal supply is decreasing, and that the cost of that fuel may, therefore, be expected ultimately to advance. The predictions of such an advance, however, are not new. The same prediction has been repeated continually for several years, in the face of which prediction the cost of coal consumed in our plants per kilowatt-hour has continued to steadily decline. If, therefore, we invest in New England water powers, expecting that our profits are to come from the expected shortage of coal supply and the consequent higher comparative value of water power, we should first decide whether or not we wish to reap the benefit of that profit ourselves or allow posterity to do so.

I have limited my remarks to New England because I am

more familiar with the conditions which are prevalent there. I have no desire to reflect by implication on any hydroelectric development past or prospective which any member of this Institute may have investigated and approved. But I wish to point out that the majority of men with whom I have talked regarding the general hydroelectric proposition seem to have in mind Niagara Falls, or some one of the few very large water powers in the country, and to bear but little in mind the very large number of moderate sized powers in our hundreds of streams. I have regarded this fact as unfortunate, and from information furnished to me I am led to believe that our governmental authorities have an entire misconception of the value and importance of water powers. If there is any prospect of the so-called gigantic water power trust that has been exploited more or less in the press, I believe our government should go slow in discouraging such an organization, not that I am in favor of trusts or monopolies, but because in the formation of any large syndicate competent advice and assistance is at once sought, and there is a much smaller chance of blundering in estimated cost of construction, operating expenses, fixed charges or receipts, with consequent inevitable financial disaster, and if the justifiable development of the really useful water powers of the country is retarded by arbitrary restricting laws, the country, not the investor, will suffer.

Julian C. Smith: I have only a few facts to bring before the members of the Institute, but before giving the results of several years' operation, I would like to indicate briefly the conditions of operation. We have a large power station, two separate pole lines about 100 miles long, a large receiving station, where almost all of the power, about 95 per cent, is taken. The pressure is 50,000 volts.

I have tabulated the results of seven years' operation of the Shawinigan system in two classifications: first, what might be termed a geographical one; the second deals chiefly with the causes of interruption. I have called an interruption of service, any actual interruption to the service delivered. As all of this service is delivered through synchronous motor sets, this classification includes many interruptions which might on other systems be classed merely as disturbances.

TABLE I

Transmission lines 27 per cent.
Lightning 21 per cent.
Sub-stations 11 per cent.
Power house 24 per cent.
Terminal stations 13 per cent.
Unknown 3 per cent.

TABLE II

Elements 8 per cent.
Interference 7 per cent.

Operators 20 per cent.
Lightning 21 per cent.
Breakdown of machinery 21 per cent.
Breakdown of insulators 11 per cent.
Bad construction 11 per cent.

The first table requires no explanation. The second, however, may be elucidated as follows:

By " Elements " I mean such interruptions of service as were caused by exceptional and extraordinary conditions—forest fires, hurricanes, floods far beyond the average, or ice movements of exceptional severity.

By " Interference " I mean interruptions caused by persons not employed by our company. This includes such causes as farmers blasting stumps near the lines, malicious interference, shooting at insulators, moving houses under the transmission line, etc.

By " Operators " I mean all those interruptions caused by the company's men, either through carelessness or ignorance.

By " Lightning " I mean the interruptions caused at the time of the storms—doubtless some of the interruptions under breakdown of insulators should be put under this classification. Under classification " Breakdown of machinery," I have put all interruptions caused by generator troubles, exciters, transformer burn-outs, switch failures, etc. Under " Breakdown of insulators " I have put all shutdowns caused, or apparently caused, by insulator troubles. This includes burned or broken pins, burned poles, and cross-arms. Under " Bad construction " I have tabulated the interruptions caused by the immediate failure in service of new apparatus or interruption caused to the operation by reason of construction in the neighborhood.

It will be observed from Table II that the three main causes of troubles are operators, lightning, and machinery.

The number of troubles caused by lightning and machinery is becoming less every year. By the use of better lightning arresters, protective relays, etc., the lightning disturbances are being reduced. By the more rigid testing of machinery, the making of trial runs, lasting some days, the use of much heavier and better oil switches, and the use of machinery better adapted for the purpose, the trouble from this cause is also being reduced.

The troubles caused by operators is a different story. There are two sorts of errors made by our men, one due to ignorance and the other to carelessness. We endeavor to give the men a thorough training and limit the number of men who actually handle the switching operations. There is a large personal element involved, however, as the operation of a large station calls for men who are content to perform monotonous duties for long periods of time, and yet find these same men keen, self-reliant, cool-headed and active in case of emergency. I wish that other members of the Institute who have had operating experience would state how they have met this problem.

Henry L. Doherty: Mr. Doane calls attention to the fact that our fuel beds were not only fuel beds, but immense beds of fertilization products. That subject was in my mind when I wrote the paper, but it was not included. Coal distilled in an ordinary gas-house retort will yield about 5 lb. of ammonia per ton of coal distilled; I say this in the absence of reliable data, but my recollection is that it requires the equivalent of about 30 lb. of ammonia to fertilize an acre of ground, in the form of ammonia sulphate. Such fertilization would provide double the average production of the wheat lands of the United States. I think it can safely be assumed if all of our coal were gassified in coke ovens or retorts, it would add at least $500,000,000 to the fertility of our soil. Considerably over one billion dollars would be added to our farm products if the bituminous coal now burned in our boilers was gassified by the Mond system and the resultant ammonia used for fertilization. From this it will be seen that enormous farm-product wealth lies in our fuel beds, if it can be made commercially available.

Mr. Doane, Dr. Hutchinson and Mr. Stott called attention to the feature which I attempted to bring out in my paper, that at 38 per cent load-factor the steam and the hydraulic plant can be operated at equal cost, below that the steam plant at lesser cost and above that the water-power plant at a lesser cost. Mr. Doane specifically brought out the point that I was seemingly contradicting myself when I stated that it was possible to install water turbines, even though they were only run 100 hours each year. It must be remembered that we cannot take our average investment cost for a hydroelectric company in figuring what we can do in the way of additional installation equipment, because the main preparation expense is often work on the river, perhaps producing no physical property, or which cannot be seen, like the blasting out of a channel or something of that sort. Then there are other preparation expenses, which are enormous. With the type of simple development mentioned, however namely, simply a dam across the river and the water flowing directly to the turbine, and flowing from the turbine to the river below, while the total cost for the water power and transmission lines might be as much as $400 per horse power, perhaps the additional cost of adding water-power units might not be over $35 per horse power. We would then have only to figure fixed charges on an additional $35 as the investment for each additional horse power, thus verifying Mr. Stott's curves, where the steam plant and hydraulic plant, by virtue of the lesser fixed charges, show higher economy on a low load-factor. An additional installation of water wheels for carrying the flood flow of the river works out in the same way. But these cannot be depended on to furnish capacity; they furnish current only, because there is not both water and capacity to keep them running all the time.

The country is influenced by the belief that an attempt is being made to control these water powers by a so-called trust.

I have no doubt that the public can be induced to abuse anything that they believe is going to result in trust control. That is an awful bugaboo to them. The same opinion exists regarding the so-called watering of stock. The public has been taught to believe that the capitalization beyond the actual cost of any property means the watering of stock. I do not see why the cost of a property need represent its capitalization. Let us assume there is a water power, possibly in the northern part of this state, and let us assume that we can buy the necessary land and riparian rights, etc., for $50,000. Let us assume further that we can take another $950,000, and complete a plant having a hydroelectric capacity of 10,000 kw. That means an investment of $1,000,000 of real money. We must take all the risks, and if it is not a success we are the losers. We would be very deficient in mental ability if we were willing to invest $1,000,000 in a plant which might be worth $1,000,000 and no more. We certainly would be foolish to put money into it unless we had the possibility of making the plant worth $2,000,000. If we believe it is going to be worth $2,000,000, and if we put our money in it, believing that it will be worth $2,000,000, we are not doing any one any injustice if we capitalize it at $2,000,000, provided there is no misrepresentation of the facts. If things are worth only what they cost, then that must end the revaluing of our real estate, because there is a remarkable example of a value away beyond the original cost. Assume that a plant which cost $1,000,000, had proved a failure, had proved its inability to earn interest on a single dollar; surely it could not be contended that that plant is worth $1,000,000, because it cost that much. In other words, the cost of a thing does not represent its real value.

Mr. Buck does good service in calling attention to the fact that the public have a well-developed case of hysterics—although he did not put it so strong as that—over water powers as one of our natural resources, and the growing fear that some one would develop these and reap a profit, while very little has been said about the other natural resources, all of which have proved equally, or even more profitable than water powers. That point was brought out by Mr. Townley, who remarked that the one to benefit primarily by the development of the water powers of the country is the public, and not the capitalist. The capitalist can find other places to put his money.

Mr. Martin says that an interruption of service, under the plan suggested in my paper, might produce a very long period of the operation of the steam plant. I did not attempt, purposely, to give full details as to the plan of insuring service. It was not intended that insurance should be required beyond the time necessary to put the steam plant in operation, which we would assume would be done under different conditions all the way from one half hour to two hours.

Mr. Stott stated powdered fuel could not be used in any type

of furnace. I have had some experience in using powdered fuel and do not hesitate to say it can be applied to any class of service, although I agree with him that powdered fuel cannot be applied to ordinary furnace practice developed for producer gas, or other gases of much lower flame temperature, which contributes heat to the bounding surface.

Mr. Ryerson spoke of a contract that had been made for the utilization of waste water. As a favor to the other engineers who are interested in this class of work, Mr. Ryerson might contribute a written discussion telling us more about that contract. I have no doubt that such a contract would make money and make a slightly profitable water-power plant more profitable to its owners. Mr. Ryerson also spoke about special rates for off-peak business, and rather drew the inference, from my paper, that I held that non-coincidence of simultaneous peaks is a legitimate profit for the central station, and that they should charge the same, whether the consumers' peak occurs at the time of their simultaneous peak or not. I did not mean that inference to be drawn, although I think it is warranted. It is my opinion that the consumer should pay for what he would be compelled to furnish himself, but if the company sees fit to make any certain rate for the sake of getting business, which is extremely favorable to them, due to the fact that the peak occurs at some time when it is not a tax on them, they certainly should have the right to do so. I believe we should be allowed, even where we are strictly quasi-public corporations, to take any business that creates more revenue than its specific cost, on the assumption that it still leaves something as a contribution toward our overhead burden that will lessen the burden on other consumers. In other words, we should not be forced to figure against all business, whether the traffic can bear it or not, its proportion of the unavoidable overhead expense.

Mr. Ryerson also called attention to the point that the peak of the consumer should not be taken simply for the year, but for the term of the contract. In that respect I think Mr. Ryerson is right. We are not simply interested in that year, and if it is possible to do that we ought to put it on the basis, as nearly as possible, of what the consumer would have to do if he were to furnish his own plant, for there he must not only pay for the peak he uses, but he must anticipate, provide, and pay for the peak he expected before his actual demand was experienced.

Carl Schwartz (by letter): One of the best features of the paper presented is that it touches upon almost every problem in connection with hydroelectric development. There is one question particularly that seems to be in a rather unsettled condition—the amount and most economical kind of auxiliary power to insure against interruption and to improve the load factor.

If the first costs of a hydroelectric development are high, the fixed charges will frequently exceed those of small heat power

plants of prospective consumers; taking their business then, usually means relying on the diversity-factor of the load and on an auxiliary power plant to carry the peaks. The investment for auxiliary power will depend for instance, among numerous other questions, on the cost of the hydroelectric development itself. If its cost per kilowatt is large, to be a paying investment it should allow operation with a high load-factor. On the other hand, the installation of auxiliary power increases the investment still more so. The question of auxiliary power capacity will always be a matter of detail calculation for each particular case.

The merits of steam or gas power, however, for auxiliary plants can generally be compared and the following comparison is submitted.

Taking the steam turbine station at, say, $90 per kilowatt, and the cost of coal at $3 per ton, we find that between 25 per cent and 30 per cent station load-factor fixed charges and running charges balance each other. If, therefore, the station load-factor is lower than, say, 25 per cent, the station should be built at low first cost. If higher, say 30 per cent, it will pay to install refinements that may slightly raise the first cost but improve the economy. The same reasoning applies to a gas-power plant, except that if we take the first cost at about $140, the fixed charges will overbalance the running charges until the load-factor exceeds 60 per cent.

It is thus clear that if a gas-power station were to be given preference over a steam-turbine station, the auxiliary power plant should operate under a good load-factor. As this is ordinarily not possible, the steam-turbine station should be the best type of auxiliary plant. Its lower first cost and high overload capacity compared with the gas plant makes it serviceable for low load-factors and allows the bulk of the load to be supplied from the water-power plant where the operating expense is an insignificant item. The design of such a steam turbine plant and its method of operation will depend on the conditions to be met; and there is no difficulty in making, if desired, the design most economical for a certain load-factor and intermittent operating conditions.

An ingenious plan for insurance against interruptions of service is outlined in the paper, but it supposes the use of a steam station of the full capacity of the hydroelectric plant. This must considerably increase the fixed charges and thus the costs of the service to consumers. This amount of insurance may be required, for instance, for light and power service for a city, but it would be prohibitive for purposes where only a low price of current can successfully compete against or replace other service or create new industries.

The financial standpoint is probably the most important feature to be considered, for the reason that all engineering calculations, whether they concern the amount of power advisable

to develop, the methods to do it, whether duplicate lines or auxiliary power are advisable to install, etc., are based upon financial considerations. Inasmuch as in hydroelectric plants over 80 per cent of the cost of current is made up of fixed charges, it is easy to realize the importance of the correct valuation of depreciation. The depreciation period should not be too long, say not more than 15 years, because of possible changes in the art of engineering. For instance, the generation of current by heat is still very inefficient, and we may some day see great improvements which might affect in some cases the valuation of hydroelectric properties were the depreciation period too long.

C. P. Fowler (by letter):

The Value of Water-Power Securities

1. *Labor.* Hydroelectric plants differ from other enterprises in that the number of wage-earning employes is comparatively few and of a highly intelligent kind, the probability of differences between employer and employe, and of strikes, are thereby minimized. Furthermore, freedom from difficulties of fuel supply incident to strikes on railroad and at coal mines, freight congestion, etc., tends to stability of earning power for this class of security.

2. *Raw material.* Large investments in raw material and fuel are unnecessary with hydroelectric plants as with industrial enterprises and steam plants.

3. *Depreciation.* The amount that is necessary to set aside annually to cover depreciation for hydroelectric plants is probably not more than from one-third to one-half of that necessary with an equivalent steam plant. This amount even bears a relatively smaller ratio to the depreciation rate of industrial plants where, in addition to the depreciation of machinery, a certain amount must be set aside to cover goods that have become unsalable.

4. *Operating expense.* Another feature, peculiar to hydroelectric plants is the possible large increase in gross earnings without a proportionate increase in operating expenses. To illustrate this point, I give below a tabulated statement of the ratio of operating expenses to gross earnings of a hydroelectric development of which I have knowledge, covering a period of five years of operation.

First year	53.5	per cent
Second year	32.4	"
Third year	30.0	"
Fourth year	23.0	"
Fifth year	23.0	"

During the five-year period referred to above, the gross earnings increased over four times while the operating expenses for the fifth year of the same interval were less than twice those of the first year of operation.

5. *General.* These conditions indicate the small demands made by hydroelectric plants for working capital compared with other undertakings. This is of great importance in times of financial stringency such as were experienced in 1907.

The Relation of Water-Power Development to the Conservation of Our Natural Resources

Mr. Doherty very properly points out the interrelation of water-power development and the conservation of our various sources of fuel supply. Our chief fuels are wood, oil, and coal. Wood fuel is now almost a thing of the past, oil although used extensively in some parts of the country is of limited supply, and before long may cease to be an important factor in the problem. Coal, therefore, is the chief remaining fuel; but when it is remembered that the increase in coal consumption in the United States has doubled during each decade—a greater rate than the increase in population—the necessity for prompt measures to reduce the drain upon our coal deposits at once becomes apparent. This may be largely accomplished by a more complete harnessing of the large number of our water powers now going to waste. Recently I have estimated the value of coal saved yearly by only four hydroelectric developments located along the Canadian boundary to be in the neighborhood of $3,000,000.

Calculations on Depreciation

In reference to estimates concerning depreciation of plant, I agree with Mr. Doherty that in order to arrive at a reasonable figure covering the entire property, it is essential that the useful life of each element composing it be taken up in detail, rather than resorting to the frequent practice of using a blanket depreciation rate covering the complete plant. It is also properly conservative to use a depreciation rate which is the result of the investment of the annual depreciation fund at prevailing savings bank interest rates during the period of the estimated useful life of the portion of plant under consideration.

J. Lester Woodbridge (by letter): I cannot permit to pass unchallenged Mr. Doherty's brief reference to the use of storage batteries as a protection against interruptions of service in hydroelectric systems. I hardly feel that a sufficiently thorough investigation of this subject has been made to warrant so sweeping a conclusion; in fact statements in other parts of the paper indicate that this conclusion could not have been based upon very complete data.

The author practically admits the necessity of providing some means for insuring continuity of service in the class of systems discussed, and the problem resolves itself into a determination of what character of apparatus will give the desired insurance at the least annual cost including operating expenses, depreciation, and fixed charges. In order to solve

this problem it is of course necessary to have accurate data as to the annual cost of the different schemes proposed. The author appears to favor an auxiliary steam plant for this purpose, but in stating that he has never seen an efficiency curve on boilers, showing their economy from no load to full load, he has apparently admitted that he lacks at least one factor necessary to a complete solution of the problem. In cases where the cost of fuel is high and the character of service to be rendered requires that a steam plant shall be kept constantly ready to take an emergency load, this factor may be a most important one.

It is, however, the figures on the other side of the equation; that is, the annual cost of a stand-by battery, that I would particularly discuss, as I fear that Mr. Doherty's statement has been based on more or less misleading information.

The use of a storage battery for purely stand-by service is, in this country at least, of comparatively recent origin. In the early days of storage battery history there was no such thing as a purely stand-by battery. The man who made a considerable investment for a storage battery plant was not satisfied unless the battery was kept constantly at work. He was satisfied to install three generating units in his power plant and permit one of these to lie idle as a spare unit from January 1 to December 31; but not so with the storage battery. That must be worked or he was not getting the return for his money. A large part of this work was of course legitimate and was work which a storage battery could be called upon to do economically, using the word in the broadest sense of the term; but a very considerable part of this work was in many cases absolutely unnecessary and could have been handled much more economically by the generating units. In either case, however, the work done was far in excess of that required from a stand-by battery. On this account the first cost and maintenance charges for a battery which is limited to strictly stand-by service will be considerably less than past experience would indicate, and the great bulk of the data on which we might draw for information as to the commercial results of the operation of a storage battery is therefore quite useless in the present problem.

Within the last year or two there have been put into service several large storage battery plants especially adapted for this class of service. The plates are of a type designed to give the maximum capacity, particularly at high rates of discharge, with minimum weight, floor space, and first cost. These batteries are not designed to handle heavy peak discharges every day, and are not so used, but are held strictly in reserve ready to take up the load in case of any failure in the generated power. Such discharges occur only at comparatively infrequent intervals and although the question of maximum durability under heavy work has been subordinated to other considerations in the design of the plate, the depreciation and maintenance of these plants

will undoubtedly be exceedingly low. Information on investment cost for this type of battery is, ofcourse, available and shows an appreciable reduction from that for the standard types.

I feel, therefore, that so far as the question of dollars and cents is concerned, the comparison between the storage battery and other means for insuring continuity of service should hardly be dismissed with so brief and sweeping a statement as the author has made. There are, however, other aspects in which this problem must be considered. The conditions to be met vary widely in different cases. There are, of course, situations in which the storage battery is not the proper solution of the problem, but the conditions, as shown by Mr. Doherty's paper, vary over so wide a range that conclusions arrived at in one particular case can rarely, if ever, be applied to another. In some cases it is possible that a combination of both storage battery and steam- or gas-engine-driven generating machinery may be successfully employed. The character of service required will also have an important bearing upon the problem. To quote Mr. Doherty's own words:

> The importance of continuity of service varies in degree with almost every customer served. To some industries a mishap which causes even a fall in voltage or a change in frequency may be a serious matter.

I believe that many cases will arise in which the storage battery will be found the only means for producing the desired results and will be adopted even in the face of increased financial outlay.

The above remarks apply to the application of a storage battery for strictly stand-by service. There is, however, a wider field than this for the storage battery in connection with hydroelectric developments, for carrying occasional peak loads beyond the capacity of the generating machinery. So long as the power marketed does not tax this capacity at any time, there will be no excuse for such service from a battery; but as soon as the limit of the power development is reached, there will in many cases be profitable situations for storage battery installations for increasing the station capacity where further increase in the water power development would be impossible or prohibitively expensive, and the length of the peak so short as to render steam generation highly inefficient.

W. E. Winship (by letter): That portion of Mr. Doherty's paper dealing with methods and equipment to insure continuous service is of special interest to me, but I wish to take exception to the statements that the investment and cost of maintaining storage batteries practically preclude their use for this purpose. If absolutely continuous service is required their use is necessary, as they offer the only practical instantaneously available source of electric power.

The entire storage battery situation has radically changed during the last few years. Experience has taught what constitutes proper operating conditions in order to obtain a long

life of plates and other parts. Progress has been made in the direction of design for the different service conditions. Costs of manufacture have been considerably reduced. In particular, batteries for stand-by service have been made considerably cheaper, and their cost of maintenance is extremely small.

In my opinion it is almost impossible to make general deductions that will hold good for even the majority of water-power situations. The available water-flow may be ample in some cases; it may be insufficient in others at least during a portion of the time. It is probable that in all cases the latter condition will be true eventually, though this may be far removed and a temporary solution will often be the only justifiable one. There is at least one storage-battery plant—probably there are many others—installed in connection with a water power, whose entire cost was saved during its first year of operation, by shutting down the steam plant which had been used to take the peaks. This particular battery has been in service over six years, with no renewals and with little prospect that any will be required for several years more. I have intimate knowledge of a number of battery plants of from seven to nine years old without plate renewals and with none being required for several years. I have strong grounds for asserting that the pure lead Planté type of positive plate is good for from seven to nine years of life in hard service, and that under stand-by conditions it will last much longer. Planté negative plates properly made will have conservatively at least double the life of positive plates. It may be admitted that many engineers have the opinion of battery maintenance cost expressed in the paper, but they should inform themselves in regard to the performance of some of the makes of batteries with which they may be unfamiliar.

A comparatively recent development is the use of regulating storage batteries whose duty is controlled by the variation of the alternating-current load. This function, in addition to their available discharge capacity for a limited time, makes them an extremely valuable adjunct to a plant if the load is variable. Incidentally, both voltage and water-wheel regulation are obtained; these are not small points in themselves, while the plant and line capacity are both increased.

I am surprised at the apparent lack of faith in the reliability of transmission lines shown in the oral discussion of Mr. Doherty's paper. Numerous transmissions of moderate length and voltage are satisfactorily serving public utilities all over the country; and with the better insulation and lightning protection now available, it would seem that the proper step, in those cases where trouble is experienced, would be to improve the lines. With duplicate lines and facilities for rapid testing and switching, it should be practically possible to reëstablish service in a very short time. The investment corresponding to the duplicate lines need not be prohibitive, as the duplicate lines could be

designed to carry the load at maximum economy with both lines in service, but with a greater drop in voltage when but a single line is operated.

Holding either a steam or water power plant in reserve but ready for instantaneous service seems to me an extremely inefficient way to utilize apparatus; furthermore, it would not under any condition insure against a short interruption of power. Instantaneous readiness for service could scarcely be obtained with a steam plant, as there would necessarily be an appreciable interval before the boiler could respond to the sudden demand. Water wheels might respond more quickly, but their governors are notoriously sluggish, especially with low heads. Some instantaneously available source of power is necessary if momentary interruptions are to be avoided, and storage batteries form the only practical apparatus for the purpose. If the water power is insufficient to carry the total load, necessitating reinforcement by another generating plant, it would of course be much simpler to throw an additional load on the operating steam plant than on such a plant standing idle; even in this case, however, there would be grave danger of a short interruption of power without a storage battery.

Francis Blossom (by letter): Many engineers will not concur in Mr. Doherty's statement that

> The problem of reliable service on long transmission lines is much further from solution than all of the other problems that have done so much to contribute obstacles to rapid development.

The use of a long transmission line does not necessarily entail interruptions exceeding in frequency those occurring on the multiplicity of feeders frequently served from a steam station located nearer the point of power consumption.

The continuity and reliability of service supplied over a transmission line is largely a question of the mechanical and electrical strengths of the line. Assuming proper design, mechanical strength is a function of purchased safety-factors, and the same is true—but to a lesser extent—of electrical strength, which, however, is more subject to stresses of unknown magnitude.

Mr. Martin has stated that some performance figures would be given with respect to the 15,000 kw. power supply furnished to the Pacific Gas & Electric Corporation over the transmission line of the Stanislaus Company. These show an uninterrupted line delivery over a ten months' period—from February 1, 1909, to December 1, 1909—of a 100-mile transmission line of the Sierra & San Francisco Power Company, supplying a maximum demand of some 15,000 kw. from the hydroelectric station of about 20,000 kw., on the Stanislaus River, in the Sierra Mountains, to a sub-station of the purchasing corporation at Mission San Jose. The conductors are of 2/0 copper, six-strand, hemp center, spaced about 9 ft. minimum vertical and 16 ft. horizontal distances apart on an unsymmetrical triangle,

supported by suspension insulators of five elements on single-circuit, pyramidal, galvanized steel towers, averaging six and two-thirds towers per mile.

The operating performance is tabulated as follows:

TABLE I

	Hours	Minutes	Percentage
Total period of delivery of power to purchaser......	6709	22	92.26
Total period of non-delivery of power due to cessation of purchaser's demand..........................	539	21	7.42
Total period of non-delivery of power due to interruptions caused by troubles of any nature in the generation of power..........................	23	17	.32
Total period of non-delivery of power due to interruptions caused by troubles of any nature in transmission line..................................	0	0	0.00
Total elapsed period (10 months)..................	7272	0	100.00

Philip P. Barton (by letter):

Methods to Insure Against Interruptions or to Lessen the Harmful Effect of Interruptions

In a general manner, the transmission system by means of which Buffalo and Tonawanda are supplied with electrical energy from the plants of The Niagara Falls Power Company and Canadian Niagara Power Company is indicated herewith, in Fig. 1. The installation may be described as consisting practically of a closed-loop arrangement of transmission lines passing through three great hydroelectric generating stations and through three sub-stations—two in Buffalo and one in Tonawanda—in such a way that any or all of the sub-stations may be supplied in either direction from any one or all of the three generating stations. The system as shown was completed substantially in 1907, although the third Canadian circuit was not constructed until 1908. In the 30 months during which this system has been fully in operation, there have been two interruptions to the entire power service to Buffalo, each caused by lightning. On one of these occasions, all of the American and Canadian transmission lines were short-circuited almost simultaneously by a wide-spread lightning storm. On the other occasion, the entire service would not have been interrupted except for the fact that the American plant was completely shut down for repairs to the tunnel at the time when the lightning short-circuit occurred. From July 24, 1908, to this date (January 3, 1910), the continuity of Niagara power service to Buffalo has not been broken.

The following is a statement in detail of the complete interruptions to the Buffalo service since January 1, 1905:

TABLE I

1905	
Jan. 25.	Short-circuit in transformer in customer's sub-station.
Feb. 23.	Short-circuit due to mistake of electrical fitter at generating station.
June 5.	Wire thrown across transmission line by telephone lineman.
June 5.	Transmission line short-circuited by lightning.
July 17.	Transmission line short-circuited by lightning.
July 19.	Transmission line short-circuited by lightning.
July 27.	Short-circuit in step-up transformer at generating plant.
Aug. 3.	Transmission line short-circuited by lightning.
Aug. 10.	Bale wire thrown across transmission lines.
Aug. 30.	Transmission line short-circuited by lightning.
	Total.. 10
1906	
Jan. 4.	Short-circuit on transmission line caused by wind storm.
Jan. 5.	Defect in cable insulation at generating plant.
Apl. 14.	Mistake in switching at generating plant.
Apr. 29.	Transmission line short-circuited by lightning.
May 4.	Transmission line short-circuited by lightning.
June 8.	Transmission line short-circuited by lightning.
Aug. 3.	Transmission line short-circuited by lightning.
Aug. 3.	Mistake of attendant at customer's sub-station.
Oct. 10.	Tree broken down across line by heavy snow storm.
	Total.. 9
1907	
Jan. 20.	Short-circuit on transmission line caused by wind storm.
Apl. 24.	Mistake of attendant at customer's sub-station.
June 4.	Tape line thrown across transmission line by civil engineer of a railroad company for purpose of measuring elevation of conductors.
	Total.. 3
1908	
June 22.	Transmission line short-circuited by lightning.
July 24.	Transmission line short-circuited by lightning.
	Total.. 2
1909	None
	Total.. 0

Few of the above interruptions lasted more than 5 min. In many cases the service was resumed within 2 or 3 min.

While the experience of The Niagara Falls Power Company may not be especially helpful to those who are endeavoring to transmit energy to great distances at very high voltages, members of the Institute may be interested in the statement that the central station lighting companies in Buffalo and Tonawanda scrapped their steam plants more than 11 years ago and have not burned a pound of coal for power purposes since 1898; and that

the railway company operating substantially all of the urban and interurban trolley service within 30 miles of Buffalo keeps its steam plants shut down and closed up except during the winter months, when its peak load requirements cannot be supplied economically from a hydroelectric plant.

In dealing with the subject of safeguards against interruptions to service, I think that in many cases too little consideration is given to the necessity of building up an efficient operating organization. One of the important ways in which insurance of continuity of power service is sought is by connecting up into a common network several generating plants with a number of inter-connected sub-stations. Operating complications and opportunities for mistakes multiply very rapidly with this process, and the problems of selecting and organizing and training operating forces to handle successfully such plants are often of far

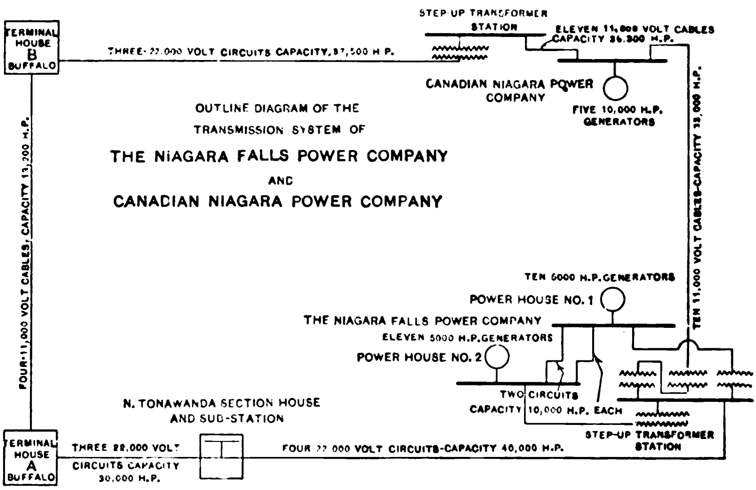

FIG. 1

greater importance than the problems of design and construction. The variety of possible emergencies in a modern power installation is very large. To prevent these emergencies, to predetermine and carry out correct methods for dealing with those that cannot be prevented, and to meet with prompt resourcefulness and coöperative team work those that cannot be foreseen, require the same kind of preparedness and discipline in an operating organization that are exhibited by a successful army in the field, and these qualities are to be acquired by similar methods in each case. I think that many engineers would be surprised, were they to make a critical analysis of the operating records of some large power installations, to find what a large percentage of accidents must be charged directly or indirectly to defective organization.

Penalties for Interruptions of Service or Insurance Against Interruptions

The only point I wish to make on this subject is the desirability of keeping contractual relations between a power company and its customers as simple as possible. I doubt whether any penalty that it is practicable to get into a contract will have any appreciable effect on the continuity of service from a hydroelectric power plant. In most cases, the service will be the best that the ability and resources of its management can produce, irrespective of the question of penalties. I think that the common expedient of a rebate of charge during periods of interruption, and perhaps for an agreed period in addition thereto, will meet the requirements of nearly every ordinary case. The plan described by Mr. Doherty seems to be ingeniously complicated. As I understand it, it simply means that the parties have agreed that to insure continuity of service a steam plant must be operated at times, and that the cost of such operation is to be divided between the parties in a certain arbitrary manner. If the method of dividing the cost is to be arbitrary, perhaps it might be simplified to advantage.

Calculations on Depreciation

Depreciation appears to be regarded by many persons as something whose magnitude can be calculated in figures of percentage accurate to the third decimal place. Two elements must be known before such a calculation can be made. The first is precisely how long a thing will last; the second is the exact cost of replacing it at the end of the period. Each of these elements is a subject for intelligent guessing rather than for refined calculation, and the best guess based on knowledge and experience of wear and tear may be upset by the uncertain factor of obsolescence. Nevertheless, some provision for depreciation must be made in every well-considered enterprise. I am inclined to think that the best results will be obtained if rules and percentages are abandoned. No two cases are alike. Each must be treated by itself. I am of the opinion that the amount to be set aside annually for depreciation should be determined somewhat arbitrarily by the application of common-sense to conclusions reached after a free and thorough discussion by the engineering and accounting and financial representatives of the enterprise. In a prospective development any figure for depreciation is necessarily a guess. In a going concern the financial situation must be considered quite as much as the physical situation in setting up reserves for depreciation.

I have been asked to give some figures on depreciation based on the actual experience of The Niagara Falls Power Company, and have had prepared a statement of the actual expenditures for maintenance and repairs and betterments for the electric generating plant and for the hydraulic motive power plant covering the period from January 1, 1900, to December 31, 1909.

The electric generating plant consists of twenty-one 5000-h.p. generators with switchboard equipment, etc. The plant is now apparently in about as good condition as when it was new. About 40 per cent of the switch gear may be described as obsolescent, although for practical purposes it is more efficient than when it was installed. At a convenient time, however, it doubtless will be replaced with modern equipment. The actual annual expenditures on this plant for maintenance and repairs and betterments have been slightly under three-fourths of one per cent of its original cost. This includes complete new windings of improved design for the armatures of seven of the generators. It is interesting to note, in this connection, that generator No. 1 put in commercial service in 1895, has required practically no repairs and exhibits no visible signs of depreciation.

The motive power plant consists of twenty-one 5000-h.p. turbines with shafting, governors, headgates, oil pumps, oiling system, etc. The actual annual expenditures for maintenance and repairs and betterments have been slightly under two per cent of the first cost of the installation. The entire plant has been kept in the best possible physical condition, but it is probable that ten of the turbines will be rebuilt within the next few years in accordance with improved designs.

C. H. Baker (by letter): I have always felt that a power engineer leans, unconsciously, toward particular kinds of power and particular types of apparatus, from which he is not likely to be weaned. Mr. Doherty, I assume leans towards steam as a motive power, while my leaning is decidedly toward the power derived from falling water. His experience undoubtedly has been most satisfactory with steam; mine has been decidedly so with water power. I am not disposed to admit that a water-power plant properly designed and constructed requires any steam adjunct at all in the sense of reserve power, although it may be well to have a considerable capacity in steam to carry either the daily fluctuating peak in a mixed service or to carry the winter peak if the service produces such a condition.

I do not recall a properly designed water-power plant where a steam plant has been introduced as a reserve. It is very common to find auxiliary steam plants in connection with water-power plants, but they owe their existence to the fact that they preceded the water-power plant, the steam plant being retained as an auxiliary either to carry the peaks or as a protection against uncertain service, as a wiser measure than to reduce it to scrap and practically get nothing for it. My belief is that a water-power plant can be so simply designed and so well constructed that even with a long transmission the interruptions to service and the fluctuation in voltage will compare favorably with the service rendered by any steam plant.

I believe that the Snoqualmie Falls plant which supplies Seattle, Tacoma and Everett in the state of Washington, has no equal from any point of view in the shape of any steam power

plant in operation on the Pacific Coast. The Snoqualmie plant operates year in and year out with scarcely a second of interruption, and although the transmission lines carry the railway circuits as well as miscellaneous power and lighting circuits, the variations in the voltage curve are almost limited to the thickness of the curve itself. The success of the Snoqualmie plant as a reliable power agency is due: first, to the absence of a flume which the river itself takes the place of; secondly, to simplicity of wiring and switching arrangements, both at the primary and terminals; and, thirdly, to a well built duplicate transmission line following a right-of-way cleared beyond peradventure of all trees and other features which might challenge the continuity of the service.

It is particularly important that the transmission conductors whether of copper or of aluminum, should be stranded cables. I prefer aluminum, principally because of its lightness. My judgment is that the extra investment necessary to incorporate an auxiliary steam plant—if incorporated in the water-power plant itself—in the shape of duplicate pole lines, extra conductors, concrete or steel towers, a spare unit at the generating station, the best type of insulators and lightning protection, and spare transformer units at both the primary and subsidiary end will lay a foundation for a service as reliable as that offered by any steam plant. I also believe that flumes should be replaced by excavated canals or tunnels wherever possible.

I concede, of course, that no two water-power situations are alike. Among them all there will be a few conspicuous for desirable features with which nature has endowed them. There will be others which by their very nature will be almost impossible situations. Then there will be a large number having only average merit. If one could design his own water power he would avoid extremely low heads, meaning that an unusually large volume of water per horse power would have to be handled for power production; and he would avoid extreme high heads where great pressures and high velocities would be encountered, requiring great and unusual strength of apparatus, and developing features inimicable to good regulation. The ideal head would neither be 10 ft. nor 3000 ft. but about 500 to 600 ft., thus calling for impulse wheels in place of turbine wheels.

A word with reference to the relation of power companies in general to the public. An asset item of as great value to a power company as its boilers or its water wheels is that of popularity. This item affects very materially the earnings of a company and the value of its franchise rights, which emanate from the people. A good plant and a poor and short-sighted management may not be as good an investment for the bondholders as a poor plant presided over by an able and courteous management which is ever ready to doff its hat to the public. The company must have public confidence, and the eye of suspicion must not rest upon it in regard to any of its measures or actions. If

the public knows that the company is in league with corrupt councilmen for the purpose of gaining lasting and unreasonable privileges, then every person in the community will disparage it at every opportunity.

The disposition quickly to repair troubles, to adjust complaints as to bills, and to not ask too much of the public in way of franchise privileges is in line with Mr. Doherty's remarks, and my reference is simply to emphasize what he has said upon the subject. I have witnessed the situation of a water-power company being out of commission due to a fire, and the opposition company endeavoring to take advantage of the situation by offering its service at once, coupled, however, with the condition that long-time contracts be entered into. The afflicted company was so popular, however, that stores, residences, etc., burned candles for about 36 hours rather than entertain any propositions for relief whatsoever coming from either electric or gas light opponents.

The ideal situation in a water-power business is a water power company serving large industries like flour mills, steel works, etc. Mr. Doherty's optimism makes it clear that most water-power companies may be able in the future to select their own business. This is the kind of business that such companies would naturally prefer, for the reason, as he stated, that the service may be for some purposes less refined than where lighting and street car services are involved. Besides thus developing an uncomplaining class of customers, the situation is simplified by having fewer circuits, fewer meters, fewer accounts to keep and fewer although larger collections to make. A mutuality of interest may at the same time be developed by the power company investing in the securities of this class of customer which it may serve.

If a central station handling mixed business of the community exists, the power company may furnish it a certain allotment of power covering its base load, and not exceeding say one half the average peak. If there is an interruption in service under this condition it would only be partial, as the central station would have its steam plant in operation, and the patrons of the company during the period of affliction could get along with half their necessary lighting, and the street car service could be reduced temporarily one half. The power thus sold by the hydroelectric company to the central station should be accepted by the central station company, subject to the conditions which experience teaches are likely to obtain, and the price should be made accordingly. There should be no penalties, which only promote friction and bad feeling. The hydroelectric company will maintain no better behavior due to any code of penalties. In such an event it is the greater sufferer by virtue of losing reputation and revenue.

If the hydroelectric company desires to handle the mixed business of the central station, it should preferably have its

own central station do its own distributing as well as generating, and deal directly with the members of the public without the intervention of another company. In this way the consumer feels that he is getting his power first hand, and at more nearly its reasonable value, and he is also in a position to know whom to commend for a good service and whom to censure and have recourse upon for bad service.

H. F. Parshall (by letter): I have been called upon to carry out or report on very many power installations, the majority of which have been founded on more or less sound commercial lines. In many cases, however, the rate of growth of demand for power has been overestimated. In the design of a central power installation it is necessary to take into consideration in the original arrangements the character the installation may ultimately assume. In the case of hydroelectric undertakings it frequently happens that a good deal of the initial investment has to be on a scale to provide for the size the installation may be expected finally to grow to. The same remark applies in certain details, but to a lesser extent, to steam installations. In both cases it has been found as a matter of practical experience that the demand does not arise before the ability to supply it and growth is frequently very slow, even after the supply has been demonstrated to be both advantageous and reliable. It follows, therefore, that any type of power installation is likely to be subject to heavy initial interest charges. In some instances engineers have been over-sanguine as to the time required for completion, over-sanguine as to the prices that could be realized with any reasonable rate of growth, and over-sanguine as to the time such growth would be sufficient to earn fixed charges.

Looked at from a financial point of view, the time-element is the principal deterrent. Any hydroelectric installation sensibly located, is, in the long run, likely to become a valuable property, although the original projectors may not be the ones to reap the benefits of the undertaking. Owing to many engineers having overestimated the possible earnings of power installations, many financial houses have become extremely pessimistic on the subject. At the present moment I think it may be fairly stated that, from a financial point of view, many of the hydroelectric power installations in the United States are of the future rather than of the present. But there can be no doubt as to the ultimate value of this class of undertaking. A paper of the character of Mr. Doherty's is of especial value in that it should tend to restore an equitable balance between the optimism of the engineer and the pessimism of the banker.

I recently heard the opinion expressed by a banker who is associated with the development of hydroelectric power schemes in Switzerland, that eventually such installations had won out, and that hydroelectric undertakings were a good class of security to have on a banker's shelf, since they were constantly appreciating in value. This opinion is based on installations that have

been working for some time, and on the smaller class of installation where the initial capital required for future development was comparatively small.

In building a railway it is frequently possible to install a structure more or less temporary, so that the capital charges are small, until such time as the traffic justifies something more permanent, so that "scrapping" at the opportune moment is of less importance than the interest charges that would have been incurred on a permanent class of installation. Unfortunately, this course cannot be followed out in a hydroelectric installation, and, as stated in the beginning, this introduces the all-important factor as to time.

I think most of the hydroelectric installations have been well designed, although in some cases greater attention should have been given to the duplication and stability of lines. Here again, time-element and capital have to be considered.

In many installations the question of a stand-by plant has to be seriously considered, and I do not know that there is any general solution in view. Both gas engines and oil engines are extremely expensive to install but are efficient in the matter of fuel consumption. The steam-turbine station is the cheapest to install and maintain, but in some cases the stand-by charges are considerable.

Generally speaking, I do not suppose that my opinion differs at all from that of all other engineers; namely, the less the extent of stand-by plant, the less the likelihood of its being called into commission, and the more attractive the hydroelectric installation. Once the supplementary stand-by power stations become a necessary part of a water-power scheme, the commercial result becomes problematical and often evanescent.

Having regard for the natural conservatism of the banking fraternity, my advice is that engineers should be especially careful to catalogue the risks as fully and as explicitly as the prospective and possible advantages, so that a useful field is not needlessly handicapped by preliminary mistakes.

J. F. Vaughan (by letter): A feature too often slighted in hydroelectric plant design, but essential to the best economy of operation, is some adequate provision for recording the flow of the stream. The usual method of determining flow by guage heights taken once or twice a day without reference to the rise or fall of the river at the time of observation or the possible changing of the cross-section of the river is often inaccurate or a wholly unreliable indication of the power of the stream, or of capacity for further development by storage, steam supplement, or otherwise.

Wherever possible, measuring weirs should be provided and where too costly, or otherwise impracticable, every other available means of determining the stream-flow or of checking other measurements should be taken; as for instance by:

1. Calibration of the dam-crest as a weir, using a continuously

recording gauge to determine the height of water above the crest and the variation of the pond-level.

2. Calibration of sluice gates, fishways, etc., in the same manner.

3. Calibration of the water wheels themselves to determine the flow through them at different gate openings, and recording of backwater level.

4. Calibration of flume or canal at a given section by current meter or weir, and use of a recording water-level indicator.

5. Measurement of pipe line or penstock flow by pitot tubes (preferably recording).

6. Indication of flow by venturi tubes, or even by friction head losses measured at sufficiently remote points in the pipe, etc.

These should be supplemented by meteorological observations wherever there are insufficient government stations.

Not only should designers provide every reasonable facility for keeping the most accurate records of the power available and used, but operators should see that the records are properly kept and the accuracy of the methods maintained; for without such records, neither can the owners get the maximum return from their equipment, nor can they properly determine the true value of the power nor the extent to which it may be further developed.

E. C. Brown (by letter): The impression generally prevails that the Federal Government is unfavorable to the liberal development of water powers. This, perhaps, is taking an extreme view of the attitude of the authorities at Washington. But, be this as it may, the effort now making by Government officials and an association devoting itself to the conservation of the country's natural resources cannot but exert a favorable influence on our water courses, since the devastation in recent years of vast tracts of woodland has very appreciably affected the constancy of developed water powers. Let us hope that any retardation, by reason of the general policy of the Federal Government against development of water powers, may be counterbalanced by the efforts now making for husbanding woodlands so essential to the permanency of streams.

Calculations on Depreciation

Under Calculations on Depreciation the writer would submit that hydroelectric plants should be built with at least three views always in mind:

1. Thoroughness to insure stability of dam and all work connected therewith. Inferior construction in this field of operation, probably more than any other, might lead to most disastrous consequences, as well as loss of considerable investment.

2. Construction with a view of obtaining every foot of available head, even though initial investment may be increased.

3. A factor of safety is generally a wise policy, when estima-

ting on water power development, by making a liberal allowance for cost of construction on the plant and figuring the dependable stream-flow a fair percentage below that which seems warranted by the measurements and statements made to the engineer by "old inhabitants of the region."

With respect to 2. About 10 years ago I was associated with a hydroelectric development that suffered a loss of nearly 15 per cent in possible power development because of the unfortunate decision to save a matter of $200,000 in flume construction instead of tunnel development which should have been made.

J. H. Wilson (by letter): In my opinion the investing public's distrust of hydroelectric projects is more fully justified than we might like to admit. The arbitrary deductions on the engineer's estimate made by those who have had experience with these investments is, I think, a serious matter. It shows that in many cases the engineers who make these estimates are professionally incompetent or do not realize their moral responsibility.

To be specific, large sums of money have been invested on engineers' reports in which the minimum stream-flow was given at from three to five times the amount justified by the available reliable data. While the lengthy prospectuses might have some merit as works of fiction, as a basis for investing money with the expectation of getting a fair return, they were absolutely valueless.

Only under exceptional conditions as to market and cost of development is it commercially feasible to develop for more than the minimum flow of water, as the cost of auxiliary equipment which ordinarily must be provided renders the commercial success of the enterprise questionable.

Most streams in their normal condition do not provide a minimum flow that justifies very extensive development. We are thus brought face to face with the problem of artificial storage, which is absolutely necessary in order to conserve our water power. As to whether this should be done by public or private enterprise we may differ, but that it should be done admits of no question.

James Lyman (by letter): Public attention was first directed to the commercial possibilities of utilizing the water powers of the Country in 1895 when the Niagara Falls Power Company started its great power house. Since that time many water powers have been developed, and what was then a new and unexplored field of engineering has now been thoroughly worked out.

Water wheels of either the turbine or impulse type have been designed with a capacity up to 15,000 h.p. and for heads up to 1500 ft. and giving a brake horse-power efficiency in the largest size up to 90 per cent. The design and construction of masonry dams to withstand extreme flood water and all conditions of

weather and climate is now as well understood as bridge building and other lines of civil and mechanical engineering.

Electric generators and step-up transformers with voltages suitable for transmission of many thousands of horse-power 150 to 200 miles with comparatively small energy losses, are of standard and reliable design.

The substantial steel towers well set on private right of way, the suspension link porcelain insulators of great mechanical strength and high insulating qualities, and the heavy stranded, hard-drawn copper cable ensure reliable service for long distance power transmission.

Before proceeding with any proposed hydroelectric development the following data should be obtained:

1. The fullest information should be obtained of the water flow throughout the year and over as many years as possible. The drainage area of the stream, the vegetation, timber lands, and character of the soil should be determined.

2. The available market for the power should be carefully canvassed, prices obtained, and actual or possible competition recorded.

3. To ensure the best returns on the investment, the hydroelectric company should control the lighting, electric railway or other power companies, using the water power developed. In other words, it should sell direct to the consumer instead of to a local company. A water power should not be developed until a good market is assured.

The majority of the water powers throughout the country are subject to a wide range of stream-flow. For two or three months of the year the flow may not be more than one-half the minimum flow during the balance of the year. To provide for this low-water season, a steam-turbine power house should be installed at the receiving end of the transmission line. The capacity of such power house should be, say, the difference between the power corresponding to the minimum flow during the year and the minimum flow during the nine or ten full months.

Such a power house would serve three important functions:

1. It would bring the capacity of power developed up to that corresponding to the minimum flow through nine or ten months of the year.

2. It would act as an insurance reserve on the system in case of possible interruption to the water-power service.

3. In long-distance transmission especially, one or more of the steam generator units could be kept running on the system, with very little energy loss, as a synchronous rotary condenser. By means of a Tirrill regulator in connection with its exciter, it could automatically maintain constant voltage at the receiving end of the line through a wide range of load and power-factor, the voltage at the water power house being kept constant regardless of the load conditions.

R. A. Ross (by letter): Until the engineer is willing to recognize that his services are only valued by the public according to the returns they give either in dividends or benefits, he will not fulfil his whole duty to the public, nor will he obtain that recognition which he deserves. Most engineers are too much wrapped up in the technical aspect of their profession, to the neglect of the commercial point of view, which has to do with the dollar. As a result, it is frequently remarked by financial men that engineers' estimates are notoriously too low. This is exemplified in the quotation given in the paper:

> We will not consider a water-power project unless, after doubling the cost, cutting the available power in two, and reducing the market price by 40 per cent it will show interest on the bonds necessary to issue.

This remark is a purposed exaggeration, designed to call attention to a situation. It is pertinent, therefore, to inquire wherein engineers' estimates have failed in this regard, and why. A number of reasons may be given, among others the following:

1. Estimates may be based on insufficient information, information which it is impossible to get, varying from that furnished by the oldest inhabitant as to the height of the water in a stream, up to reliable information by gaugings which have been carried out for a number of years. There is here a wide unavoidable margin for discrepancy.
2. The cost of certain parts of the construction, such as foundations, may be unknown and perhaps unknowable until "unwatering" takes place.
3. Estimates may be made during a period of depressed prices, and the project may be held over by the monied interests until prices have risen, when the financing is done on the old estimate.
4. Additions may be made to the enterprise which were not previously considered. It would appear that the cost of such additions would be allowed for in the mind of the financial man as extras, but it will almost invariably be found that he remembers nothing but the total amount of money originally extended or required and makes no allowance for extensions to the scheme. In fact he seems constitutionally unable and unwilling to recognize any other figure than that placed before him by the engineer for a stated case, whereas the development in its final form is entirely different.
5. Insufficient consideration to expenses other than those involved in the physical construction.

In the development of any project, the costs group themselves into two divisions:

a. Those purely engineering costs which cover the construction and equipment.

b. Those financial or business costs which cover the working capital, financing, deficits during the initial period of business, etc.

To illustrate this point, consider the following table which has been derived from an actual case of hydroelectric development

under three schemes producing progressively larger amounts of power:

TABLE I

Data	Development A	Development B	Development C
Construction			
1. Estimated cost of hydroelectric plant........	$1,895,225	$2,618,715	$3,694,386
2. Estimated cost of transmission lines and equipment..............................	1,393,287	2,009,668	2,693,299
3. Estimated cost of sub-stations and equipment.	636,488	1,051,617	1,304,315
4. Total estimated cost of plant from items at market value...........................	3,925,000	5,680,000	7,692,000
5. Shortages, construction plant unavoidable extras, and mistakes, etc.................	275,000	350,000	500,000
6. Total cost of physical equipment............	4,200,000	6,030,000	8,192,000
7. Engineering, with plans, supervision, and preliminary operation, say 5 per cent on Item 6................................	210,000	301,500	409,600
8. Business, legal, insurance, and accident costs, allow................................	75,000	100,000	150,000
9. Total cost of enterprise apart from financing.	4,485,000	6,413,500	8,751,600
Organization and Financing.			
10. Organization and promotion, charter, printing, brokerage, etc.....................	75,000	100,000	150,000
11. Interest during construction, on Items 1 to 10 at 5 per cent on face value of bonds issued below par........................	329,979	480,706	649,267
12. Normal operating costs and bond interest in excess of gross earnings say for one year after operation commences...............	55,000	70,000	100,000
13. Securing business, extra advertising, canvassing, etc., during development period as above, allow...........................	22,000	30,000	40,000
14. Interest on Items 12 and 13 for say 1 year..	3,750	5,000	7,000
15. Total estimated cash expended until earnings equal operating costs plus bond interest..	4,968,729	7,117,206	9,697,867
16. Allowance for working capital..............	200,000	300,000	400,000
17. Total cash required........................	$5,168,729	7,417,206	10,097,867
18. Additional costs of Items 1 to 9 if development *A* is increased at different times instead of the larger developments being made at once............................	——	$500,000	750,000

The engineering estimate will include Items 1 to 9, while the financial or business estimate should cover those from 10 to 17 inclusive.

The question then arises, in whose province is the estimating of such additional costs for which money must inevitably

be raised? If left to the financial man, does he do his duty; or, failing this, does he not frequently take refuge in the statement that the engineering estimates are too low? I think that most engineers who have had to deal with these matters will recognize that the latter occasionally happens. It becomes a question, therefore, whether the engineer should not in self-defence consider these financial and business items in every case to the best of his ability, which if not corroborated by the financier with his wider experience, would at least serve notice upon him that they demand consideration.

The results in the illustration given may be summed up as follows, for equipment (*a*)

Total cost of physical equipment	$4,200,000.00
Total cash required for enterprise	5,168,729.00
Indebtedness to bondholders for above cash, bonds being sold under par	6,500,000.00

In this case it will be noticed that the indebtedness incurred exceeds the cost of the physical equipment by 55 per cent.

As stated by Mr. Doherty, financiers do apply the pruning hook to engineers' estimates, but of course not to the extent indicated in the quotation. The question arises whether this does not tend to the acceptance of schemes that have not been soundly estimated upon in preference to those which have? Where a careful conservative estimate is made the costs will be high, and the application of any arbitrary rule tends to eliminate it from favorable consideration on the part of the financier, and to give the preference to an ill-considered, ill-estimated proposition showing a lower cost. In other words, the whole matter hinges on whether the engineer is to be considered as a technical man dealing with the cost of the physical equipment only, or whether he is to be considered a business man competent to deal with the enterprise as a whole?

The education of the engineer has been neglected in his relation to business. It is about time this was recognized, and his responsibilities extended to the scheme as a whole. It is only when this education has been acquired and acted upon, that he will receive that respect from the business public and financial men that his profession warrants.

M. H. Collbohm (by letter): The combination of water power and irrigation projects mentioned by Mr. Doherty is interesting and new. For a number of years electrical power has been utilized in irrigation schemes, demanding, however, only a moderate amount of the total station capacity plants. Only recently have hydroelectric plants been built mainly for the purpose of supplying electrical energy for irrigation. Plants of such order are building with considerable station capacity, making it worth while to study the special conditions met with in this new line of work. In one of the developments of this nature with which I am associated, the generating station will be designed for a final equipment of 100,000 h.p. capacity.

The power for irrigation only is used for a certain period in the year comprising about 6 months. The new problem is, to find a market for the electrical power during the rest of the year. If commercial conditions would allow the use of the surplus energy for electrochemical purposes, such as fixation of atmospheric nitrogen, production of calcium carbide, etc., the question would be solved. However where such is not the case a market may be created by selling the power cheap enough to compete with coal or oil for heating purposes. This kind of market does not interfere with that for irrigation, as their respective seasons do not overlap. The sale of power for such a purpose would probably not bring any profitable returns, but it might cover the running expenses and fixed charges.

The problem of reliable service from long transmission lines is indeed not yet completely solved. However, with duplicate lines on modern steel towers and designed with due regard to the severest conditions likely to arise, with the suspension-type insulator, and frequently grounded guard-wires of copper-clad steel of proper size instead of ordinary galvanized steel, (as recently discussed by the writer) the reliability of a transmission line would be considerably higher than that heretofore obtained.*

The equipment outlined in the paper to provide against interruptions serves as an emergency arrangement to help out in case where an interruption has already taken place at some point in the system rather than a means to provide against such interruption. The usual cause of interruption to service in a station comes from lightning, atmospheric and internal, as produced by arcing grounds etc., entering over the transmission line. To provide against interruptions from this cause the electrolytic lightning arrester in connection with choke-coils is used satisfactorily. As a further protection to station apparatus, iron wires of high permeability can be substituted for the copper wires commonly used for high-tension leads in the power house. The protective action of the iron wires is based upon the skin effect produced by the very high frequency of lightning, thereby increasing the resistance of the iron wire enormously.†

It appears doubtful whether financial aid can be obtained to install equipments that are kept running only for immediate help in case of emergency. The fixed charges and operating expenses for such an equipment would tend materially to reduce the net income of the plant, because its operation is almost entirely unproductive. The money that would be required for such an equipment could possibly be spent to greater advantage on the transmission line, by running each line (in case of a duplicate circuit) on a separate right-of-way—which is very seldom done on account of high cost—and by providing more

* See *Electrical World*, May 20, 1909.
† See article by the writer in the *Electrical World*, Dec. 2, 1909.

guard-wires of non-magnetic material and large cross-sections above the lines, grounded at every tower, to take care of the heavy currents inherent in atmospheric lightning, Lightning arresters at various points along the line would also materially reduce the danger to insulators and station apparatus.

H. A. Storrs (by letter): Mr. Doherty's comments must appeal to all engineers in the West, who are in a position to know the effect of the present conservation movement on hydroelectric enterprises. His remarks are specially opportune just now, when the Government, through its officials, is calling for legislation and shaping policies looking to better control of our natural resources. It is true that in the past the Government's efforts to exercise control over water-power developments have been "largely misdirected or very generally misunderstood." Especially does this seem to be the case from the point of view of those who have found the former untrammelled conditions conducive to large gains on small speculative investments. It is not so much a matter of inducing public officials to take the "proper attitude" toward the development of our water powers, as of bringing about proper legislation to enable public officials to have some definite basis of authority on which to act. Our government officers, if given definite, comprehensive laws under which to work, and sufficient funds to enable them to perform the required work, can furnish a basis for future development of the water-power possibilities of the country that will give a stability to hydroelectric enterprises not possible under the present chaotic conditions.

As intimated by Mr. Doherty, there is need of "intelligent planning and engineering" to supplant the haphazard methods now in vogue, by which a partial development of the power possibilities of a stream is governed by a policy so ill-advised and short-sighted as to preclude, for a long time, any further utilization of the remaining power latent in the stream. If given proper authority and means, the states and nation, through their technical bureaus, could determine for each stream its ultimate power possibilities, including the approximate normal flow of the stream the opportunities for creating storage of flood flow, the sites for hydroelectric plants, etc. Estimates of cost and output of installations, based on such definite and reliable data, would be accepted by the men who have money to put into such enterprises, without the excessive "discounting" referred to in the paper. This discounting of the promoters' and engineers' statements has heretofore been somewhat warranted by the uncertainties on which many an attractive proposition has been based.

That an enterprise of the character under discussion may be undertaken on a very narrow margin of profit, if a proper examination has been made of the proposed water plant provided "the behavior of the stream is a matter of reliable record for several years", is, as implied by Mr. Doherty, worthy of notice.

It directs attention to the requirement that somebody should, for several years prior to the inaugurating of a new project, have been keeping a reliable record of the stream-flow. The systematic gauging of streams, in advance of any proposed commercial developments of power, will, of course, not be undertaken except by the state or national Government.

Engineers interested in hydroelectric and irrigation projects, should be the first to urge upon the Congress the making of adequate appropriations to enable the hydrographic branch of the Geological Survey to continue its stream measurements on all streams where a partial record has already been secured, and to extend its work to all the remaining streams as rapidly as new gauging stations can be installed. The topographic branch should also be provided with funds to enable it to continue its valuable work. Its contour maps furnish at once the basis for determining the profiles of streams and probable location of power plants, as well as possible reservoir sites. Not until complete data have been obtained can the Government intelligently determine the extent of the power possibilities of its streams, or make comprehensive plans for their utilization.

Referring to Mr. Doherty's statement to the effect that the efforts of the Government to exercise some control over water-power developments seem to be obstructing rather than encouraging such enterprises, the particular case presented below will serve to show what results may be expected if the present Government policy is enforced. The National Government can not, however, under the present laws, exercise general control over the waters of non-navigable streams, since this authority is vested in the separate states. But, under the Act of June 4, 1897, the Secretary of Agriculture has full power to regulate the occupancy and use of the natural forests. Through the Forestry Service, therefore, the Government deals with prospective power plants, storage reservoirs, conduits and transmission lines, so far as they may be located within the limits of the forest reserves. The essential features of the Governments policy as stated recently by the Chief Forester in a letter published in *The Outlook*, December 4, 1909, are: first, that the right to develop water power on the forest reserves shall be granted for a limited term of years and not for all time; secondly, that a reasonable charge shall be made for the privilege granted. The application of these principles is illustrated by the following case.

Under date of November 24, 1909, permission was granted by the Forestry Service, covering the occupancy and use of certain lands in one of the national forests in Colorado, for the storage reservoir of a power generating plant. The principal features of the terms under which the permit was granted are as follows:

1. Payment to the United States, annually in advance from September 1, 1909 until the beginning of use of the waters for

which permit is granted, at the approximate rate of one dollar per acre of reservoir area and five dollars per mile of conduit for the land occupied by such works.

2. Payment to the United States of a gross operating charge, based on the total electrical output of the plant per year, at the following rates per 1000 kilowatt-hours.

For the	1st year	2 cents
" "	2nd "	4 "
" "	3rd "	6 "
" "	4th "	8 "
" "	5th "	10 "
" "	6th to 10th years inclusive	12½ "
" "	11th " 15th " "	15 "
" "	16th " 20th " "	17½ "
" "	21st " 25th " "	20 "
" "	26th " 30th " "	22½ "
" "	31st " 35th " "	25 "
" "	36th " 40th " "	27½ "
" "	41st " 45th " "	30 "
" "	46th " 50th " "	32½ "

Certain deductions are allowed from the "gross" charge in case; (*a*), the title to part of the watershed has passed out of the United States; (*b*), the conduit is not wholly on government lands; (*c*), the power is derived in part from water stored in a reservoir constructed or owned by the permittee.

The following table shows the gross charges as determined for the project under consideration:

TABLE I.

Year	Output			Rate per 1,000 kilo-watt-hours	Annual charge
	Average kilowatt per day	Average kilowatt hours per day	1,000 kilowatt hours per year		
1912	3,000	72,000	26,380	2 cts.	$525.60
1913	5,000	120,000	43,800	4 "	1,752.00
1914	7,000	168,000	61,320	6 "	3,679.20
1915	10,000	240,000	87,600	8 "	7,008.00
1916	12,000	288,000	105,120	10 "	10,512.00
1917 to 1921	12,000	288,000	105,120	12.5 "	13,140.00
1922 " 1926	12,000	288,000	105,120	15 "	15,768.00
1927 " 1931	12,000	288,000	105,120	17.5 "	18,396.00
1932 " 1936	12,000	288,000	105,120	20 "	21,024.00
1937 " 1941	12,000	288,000	105,120	22.5 "	23,652.00
1942 " 1946	12,000	288,000	105,120	25 "	26,280.00
1947 " 1951	12,000	288,000	105,120	27.5 "	28,908.00
1952 " 1956	12,000	288,000	105,120	30 "	31,536.00
1957 " 1961	12,000	288,000	105,120	32.5 "	34,164.00.

3. Payment for all timber destroyed in the forest reserve.

4. Construction of the works to begin within 18 months from date of approval of the permit; construction to be completed

and operation of the works for the purpose intended to begin within 3 years from date of approval of permit.

5. The United States reserves, conditionally, the right to purchase power at as low a price as that allowed to any other purchaser.

6. The permit is not transferable.

7. The permit shall be forfeited to the United States, if the works be controlled by an unlawful trust, or if they be used in restraint of trade in the sale of electric energy.

8. The permit shall cease and be void at the end of 50 years but is renewable upon conditions not yet fixed.

For the purpose of comparing the Government charge to be paid for the water-power privilege with the annual income of the plant, the following table has been prepared showing what per cent of total gross receipts must be paid to the Government.

TABLE II.

RATIO (IN PER CENT) OF GROSS ANNUAL CHARGE TO GROSS ANNUAL INCOME

	Sale price of delivered power per kilowatt-hour				
	1 cent	2 cents	3 cents	4 cents	5 cents
1912	0.2	0.1	0.07	0.05	0.04
1913	0.4	0.2	0.13	0.10	0.08
1914	0.6	0.3	0.2	0.15	0.12
1915	0.8	0.4	0.27	0.20	0.15
1916	1.0	0.5	0.33	0.25	0.20
1917 " 1921	1.25	0.625	0.42	0.31	0.25
1922 " 1926	1.5	0.75	0.5	0.38	0.30
1927 " 1931	1.75	0.875	0.58	0.44	0.35
1932 " 1936	2.0	1.0	0.67	0.50	0.40
1937 " 1941	2.25	1.125	0.75	0.56	0.45
1942 " 1946	2.5	1.25	0.83	0.63	0.50
1947 " 1951	2.75	1.375	0.92	0.69	0.55
1952 " 1956	3.0	1.5	1.0	0.75	0.60
1957 " 1961	3.25	1.625	1.08	0.81	0.65
Average.........	2.085	1.0425	0.695	0.52	0.417

The table shows that for the 50-year period the average payment to the Government is about 2 per cent of the gross receipts, at a sale price or valuation of 1 cent for each kilowatt-hour, delivered by the plant, and about 1 per cent at a valuation of 2 cents per kilowatt-hour.

Applying these figures to the case in hand, assuming the average value of the electric power during the 50-year period to be 1 cent per kilowatt-hour, the gross annual receipts would be about $1,000,000 and the average annual payment to the United States would be $20,000.

In response to inquiry, asking what privileges and benefits

were secured by paying to the United States the above "conservation" charge, the Forest Service replied as follows:

> The conservation charge is based on the value of the land occupied for the particular use to which the land is to be put, and on the special benefits the permitee received by reason of the care and administration of the natural forest including the protection of the watershed from fire and destructive cutting which materially affect the water sources.

The permit in hand was secured for the benefit of a project comprising a storage reservoir of 10,000 acres superficial area, of which 260 acres only were within the boundaries of a forest reserve. It follows that the annual payment of $1.00 per acre for the three years allowed for construction amounts, in this case, to only $260; whereas, if the entire reservoir had been in the reserve, a payment of $10,000 per year would have been required. It is presumed that the object of this heavy initial tax on the enterprise is to compel immediate construction of the works, thus preventing the power possibility from being held, undeveloped, for speculative purposes. Speculation in undeveloped water powers on forest reserves is still further guarded against by making the permits non-transferable.

The recommendations of the Secretary of the Interior, in his recent annual report, are generally in line with the present practice of the Forest Service, except that he would limit the life of the permit, or "easement", to 30 years, allow 4 years for accomplishing the first quarter of the proposed development, and require that transfer be made to the United States of the water rights necessary to provide for the estimated power development.

In view of the probability that, during the next decade electrical power will be applied extensively to the operation of railroads in the West, the policy and methods of the Government in exercising control over water powers located on government lands are subjects of great practical moment to the country at large. They deserve the careful consideration of engineers who are in a position to influence the trend of legislation and of public opinion.

Mr. Doherty's remarks under "collateral enterprises" are timely and specially applicable to present conditions in Colorado. Here the extensions of present irrigation systems, depending on gravity for conveyance of water, are becoming relatively more expensive each year, the earlier developments having taken advantage of the easier propositions. It is now more economical, in many cases, to resort to pumping. Electric motors driving centrifugal pumps are the ideal arrangement for such purposes, and pumping service affords a desirable load for a commercial generating station during the three or four months comprising the irrigation season. During the rest of the year, the generating capacity can often be used to advantage in meeting the extra demands for lighting and railway service. Rather than purchase power for operating the pumping plants, it is sometimes profitable to build generating stations using the power available

at some of the " drops " which frequently occur in main canals of the gravity system. Or, if cheap fuel is at hand, steam generating plants may be warranted. A complete power and pumping system using the lowest grade of lignite was recently built by the United States Reclamation Service, the writer being responsible for its design and construction. The system is located near the North Dakota-Montana line, on the Missouri River, from which water will ultimately be pumped for irrigating about 25,000 acres. The generating station is close to the portal of the mine which was opened and is operated by the United States to supply fuel to this plant. The machinery installed comprises eight 250 h.p. boilers, three turbine generating sets aggregating 1100 kw. and two 225 h.p. steam-turbine pumping units. The main canal brings water to the plant from the pumping station located on the Missouri River and the water is lifted, at this point, to higher canals, thus providing abundant water for condensing purposes. The power is transmitted to five pumping stations, two of which are distant 28 miles from the generating plant. The boiler furnaces are designed especially for burning lignite containing 40 per cent moisture, 25 per cent fixed carbon and 25 per cent of volatile hydrocarbons, and show, under usual working conditions, an evaporation better than 6.5 lb. per pound of dry coal. The plant is out of commission about 8 months each year, but it is hoped that manufacturing establishments, such as flour mills, alfalfa mills, and paper factories, can be induced to locate where power can be furnished cheaply during the non-irrigating season. A beet-sugar factory, if built adjacent to the power house, so as to take steam directly from the installed boilers, would make a desirable combination.

Irrigation systems can hardly be developed on streams having as flat a slope as the Missouri River, namely, 0.8 of 1 ft. per mile, without resorting to pumping. Where the flood rise, occurring during the irrigation season, is as great as on the Missouri River, namely, 19 ft., and the banks very unstable, it is considered advisable to mount the pumps and motors on floating barges. These are rendered free to rise and fall with the river level, by conveying the water from the barge to the shore by means of steel pipes and flexible joints. Electrically driven pumps are, of course, best suited to installations of this kind, but in some cases it has been found desirable to place the entire steam plant on board a boat. The delivery of fuel to the floating plant is expensive compared with the delivery of electric power.

Fuel-consuming pumping plants and generating stations on irrigation projects will not ordinarily be resorted to, if electric energy can be had from a water-power plant located within reasonable distance.

The above description of a pumping system depending on fuel merely serves to emphasize the fact that irrigation requirements have already opened up a new field for the disposal of electric

power from hydraulic plants in competition with power obtained from more expensive sources.

E. P. Roberts (by letter):

The Value of Water Power Securities

The value of a water power is not intrinsic. As Mr. Doherty points out, it is affected not only by the present or the near future cost of furnishing energy in the desired form to the consumer, as compared with the cost from some other source, but, from the standpoint of the investor, by the probable future comparative cost.

The Relation of Water Power Development to the Conservation of Our Natural Resources

Although the work of the Federal Government and of some of the states relative to the conservation of natural resources, including potential water powers, is proving exceedingly beneficial and the data recorded by the Federal and State Engineers are of great value to the water power engineer, nevertheless the development of water powers has, in the writer's opinion, been hampered by law and by the rulings of federal and state authorities, the result being detrimental to the development of water powers and an economic waste. Federal or State control is necessary, and, in some cases, construction and operation by the Federal Government is advisable. Undoubtedly the benefit to the community resulting from the increased interest in the conservation of natural resources will be very great, but it seems as if there were a tendency to define the verb " to conserve " as meaning " to bury."

The conservation of large areas of timber land may be advisable, and in some cases undoubtedly is so; but in other cases it is a question whether throwing such land open to settlement is not more advisable from the standpoint of economics. Where land is used for forests only, the annual value per acre of the growth on such land is very small as compared with the possible value of farm products, provided the land is suitable for farming and there are transportation facilities. In most locations, if the land is suitable, transportation facilities will follow, if they do not precede, the development of farms. The cost of supervising, developing, and safeguarding forests is very considerable, and sometimes losses by fire are great. The number of persons employed for any given area is of course far greater when it is thrown open to settlement than when it is used solely as a forest. The above is not intended as an argument against conservation of forests, but merely against unwise conservation.*

Collateral Enterprises

Occasionally irrigation and boat canals must be considered. In a report made in 1905 by Mr. W. H. Abbott, relative to a

*See article by R. C. Beardsley, *Southern Engineer*, June, 1909.

proposed power development in the Northwest, it was proposed to irrigate considerable tracts by electric pumping. The power was to be used for general purposes, so the pumping could be done at hours when other loads were at a minimum, thereby improving load-factor; in other words, provision for pumping for irrigation purposes was not to increase the cost of the water-power development. In some cases pumping could be done directly into the ditches, and in some places storage reservoirs would be obtainable at slight expense. A considerable amount of land along the bottom of the valleys was already irrigated, but there were many square miles at a slightly higher elevation which could not be irrigated except by pumping. Of course, anything which tends to improve the load-factor is beneficial, though the degree of benefit and consequently the rates which can be obtained depend upon storage capacity as well as upon other factors affecting each individual case.

The Unfavorable Features of Water-power Enterprises and Their Operation

There are few proposed enterprises which require a more careful detailed investigation than a proposed water-power development. This investigation can only be made by spending considerable money. Unfortunately, many of those interested in such proposed developments are not willing, or are unable, to have such investigation made, with the inevitable result that many water powers have been financial failures. In some cases the first cost was far greater than that anticipated; in other cases the income was much less than the amount estimated.

In some cases there are legitimate reasons why the construction cost proves to be either greater or less than the estimated cost. For example, the estimate may be based on construction at times of average flow, work being done in the months that are shown by the records to be months of minimum flow, and especially least liable to floods. If the flow conditions are different from those anticipated, even though provision be made for deflecting the water to avoid damaging existing structures, nevertheless construction may be delayed, and often at considerable expense. On the other hand, if the season is unusually dry the cost may be materially decreased. In some cases the owners may postpone construction until the season advised by the engineer has passed and then insist, perhaps wisely, that construction be commenced. The changed conditions may, however, increase the cost, causing the engineers' reputation for accurate estimating to suffer.

Even when the first cost has been accurately predetermined, and possibly also the water-flow; minimum, average, and maximum considered by weeks, months, and years, and the possible and also the advisable storage capacity carefully investigated—nevertheless in many instances the market has not been accurately predetermined, and the result may be a failure.

RATING OF WATER POWERS

The mere statement that a water power has a specified rating is indefinite, and may be misleading, although comparisons are frequently based on statements of total horse power and cost per horse power, generally on the total rated horse power of the wheels installed. The following example indicates the fallacy of considering the value of a water power as based on the rating of the wheels installed

The proposed general development is to include three water powers to operate in conjunction. One power to have materially greater fall and also greater storage capacity at its site than the others, but the other two to be located lower down the stream and consequently to be benefited by the storage capacity of the upper power. Estimates were based either on first constructing and operating the greatest power, or on simultaneously constructing and operating all three. The output was estimated to be used as follows:

1. To operate an interurban electric road. The requirements of such a road can be predetermined with a fair degree of approximation, and the nature of such load is one having great momentary fluctuations.

2. *Lighting load.* The general nature of this can also be predetermined, the characteristic being a peak load during the early evening, the peak being greatly in excess of the load at other times.

3. *Factory power load.* The general characteristics of this are a fairly constant load and mainly day load.

4. *Pumping for town and village water works.* The greater amount consists of pumping into reservoirs, and consequently furnishes an ideal load both as to constancy and as to the practicability of such load operating only or mainly at times of minimum general load. The lesser amount consists of pumping into mains, but even such load is of excellent character.

The estimated resulting general-load curve has of course its maximum at the time of the overlapping of the factory-power load and the lighting load, which would occur early during winter evenings, especially during the Christmas holidays. Although the pumping load would presumably be off at such times, nevertheless safety required an allowance for a certain portion of such load. Also, although the interurban road would operate less cars then than on holidays during the summer, nevertheless it might also be operating under unfavorable weather conditions; this might not only bring up the average requirement but also, because of bucking snow, might result in excessive momentary fluctuations. The resulting general load curve would evidently be materially affected by any considerable modification as to any one character of load.

One estimate was based on the development of the greatest power operating alone, which evidently required that the installation in such power should take care of all conditions, and

as electric generators have far greater overload capacity than turbines, therefore on account of the momentary fluctuating demand caused by the interurban road, the rated horse power of the turbines was estimated as being much greater as compared with the kilowatt capacity of the generators than would be required for constant generator load.

Another consideration was the probable result of installing storage batteries in the sub-stations of the interurban road. This would result in a power-house load having very slight momentary fluctuations, thereby decreasing the rated capacity of the generators, especially of the turbines, as the turbine rating would be approximately that required to operate the generators at constant load.

Another result would be that the capacity of the machinery in the sub-stations of the interurban road could be lessened, and the reliability of operation of the road somewhat increased; also the size of the transmission wires could be decreased, provided the size previously estimated was not already as small as the strength required would permit.

Another plan estimated was based on the use of storage batteries in the power house.

The plans above mentioned were made without reference to the operation of the other two powers referred to.

It will be noted that the useful output, and consequently the income, was practically the same in each case, but the rated horse power of the turbines was about in the ratio of two to three for the plan with storage batteries in the power house as compared with no storage batteries.

It might also be noted that the case was further complicated by the question whether the railway company, or the water-power company, should install storage batteries; and if the former installed them, then the water power company could afford to make the railway company a lower rate. It is evident that the decision as to what kilowatt capacity rates, and what comparative kilowatt-hour rates would be properly comparative, or equivalent, for each of such conditions, would require considerable study.

Estimates were also based on the development of the two smaller powers, considering whether either or both would take the peak load only, or would operate continuously; and whether they were to be placed in operation at the same time as the greatest power, or at some future date. This would obviously affect the horse power capacity of the turbine to be installed at the greatest power, but, nevertheless, the annual output of such principal power would not be affected except as the smaller powers might allow the operation of the largest power mechanism at rated rather than at part load.

Any specific case is complicated by such questions as the following: Will there be a market for secondary output, or such output as may be available at times, but is not expected, or guaranteed as being always available?

The question may also arise whether by increasing the water storage capacity, or by installation of steam power, or by making arrangements with existing steam powers, it may not be financially advisable further to guarantee the primary power or to take at least a portion of the secondary power out of such class and place it in the primary. Such changes may, or may not, materially affect the rated horse-power of the turbines installed, but may materially affect the gross and net income.

Matters Worthy of Detailed Consideration

Methods to insure against interruptions, or to lessen the harmful effect of interruptions. In most cases approximately reliable service is imperative. Assurance is impossible and how much less than absolute reliability is imperative depends upon conditions. As Mr. Doherty points out, it is frequently possible not only to tie hydraulic plants together, but also to operate in conjunction with central station plants operated by steam or gas engines. An example of such tieing together is illustrated by the plants described in the *Electrical World* of September 2, 1909, where three water-power plants, a gas-engine plant, and a central station are tied together, and in addition are connected with the plant of a manufacturing company having considerable electric output capacity, normally used for testing electrical apparatus, but which testing can stop in case of emergency.

Equipment to insure against interruptions, or to lessen the harmful effect of interruptions. If steam or other power is to be used for emergencies only, and only for comparatively few hours annually, then the financial cost is the prime consideration, and the hourly expense of operation only a minor factor; but if it is to be used as an auxiliary plant, then the importance of operating expense increases.

Another consideration is the character of labor available. And such reserve plant should be of as simple a character as possible, as in such case it is most likely to be properly handled by the force operating the water powers, and will not require the employment of a high grade stationary engineer.

Penalties for interruptions of service or insurance against interruptions. The prime object of providing a penalty is not to enforce it but rather to make such provisions as to assure the customer that he will receive the service required, which if not received will result in loss to the producer. There is, however, always the danger that by making the penalty too high the producer must materially increase the charge and the customer may pay too high for his insurance. The method described by Mr. Doherty may be applicable to some cases, but I do not understand that he suggests it as a general basis.

Methods of charging. As Mr. Doherty states, there are many methods, but the fundamentally correct one is that the customer should pay:

First, an amount depending upon the maximum demand of

the customer at the time of maximum demand on the producer. Unfortunately such basis is not always practicable and the charge must be based on the customers maximum demand.

Second, for the actual energy furnished to the customer.

Whether the maximum demand shall be based on the maximum between certain hours of the day, or whether on the maximum demand whenever it may occur during the 24 hours, and how often it shall be ascertained, will vary with the conditions. The rate at which the actual energy shall be paid for varies with the character of the load curve, including the degree of variableness of the load and the momentary fluctuations. In other words the entire character of the load affects the cost to the producer, and therefore the proper charge to the consumer.

Classes of services which can be advantageously supplied. Mr. Doherty says that "no general and complete rules can be laid down whereby the maximum load-factor can be secured to a hydroelectric company". The writer at this point suggests, as Mr. Doherty does later, that it is not the maximum load-factor which is the important item, but the maximum net income, and that there are cases where a better net income is obtainable from a low load-factor than from a higher one. If, for instance, an existing steam power plant furnishes general supply for a city, and a water power auxiliary is possible, the question will arise whether to increase the capacity of the steam plant or to develop the water power. The probabilities are that the first cost per kilowatt of capacity delivered at the steam power plant will be greater for the water power than for an equivalent addition to the steam plant, but the stand-by losses for such portion of the steam plant as are required to handle peak load may be so great as to more than offset the difference, including interest, maintenance, and depreciation charges. Under such conditions it might be preferable to have the water-power plant take care of the peak load and to operate the steam plant under approximately steady load, or at least an exceptionally good load factor. Under such conditions the load-factor of the water power would be comparatively low. Of course, other things being equal, the better the load-factor, for either steam or water power, the better the net result, but it is seldom that all things are equal.

How to develop the market selected. The points made by Mr. Doherty are, in the writer's opinion, well taken.

How to figure the amount of power which it would pay to develop. This evidently requires a comprehensive study of all the conditions. Under the above heading Mr. Doherty refers to the possible advisability of water power taking the peak load and the inequalities of load when operating in conjunction with a steam plant, and the writer has touched upon this point in connection with a previous sub-heading. It might be well, however, to add that it is important to ascertain at what time of the year the maximum peak will result, and to be sure that there will be water available at such time.

It might also be noted that the amount which can be economically expended for storage capacity can only be ascertained by comparing the estimated result with that obtainable from steam or other power auxiliaries. At the same time consideration should be given to the risk of break-down of transmission lines, and to other features affecting reliabilitiy. The possible benefit of greater reliability cannot be exactly expressed n dollars and cents, but may be a deciding factor, especially when the comparative values otherwise obtained are approximately equal.

Calculations on depreciation. Unfortunately depreciation frequently is not estimated, and the statement is sometimes made by promoters that the appreciation of the property will more than offset the depreciation, and although this may be true, the result, not infrequently, is that money is not available for replacement.

Methods to determine the accuracy of engineers' estimates. Allowing and providing for freedom of discussion and criticism by all the engineers of a corps, or several heads of an engineering force, will frequently disclose errors and also opportunities for betterment, and this can be accomplished without loss of discipline.

P. W. Sothman (by letter): I agree with Mr. Doherty that it is to the best interest of all that projects for the development of water powers should be undertaken and encouraged, which would be in accordance with the movement to conserve our natural resources. These projects should be carried on under one head with well-developed plans to insure the greatest possible development of the total energy available from our streams, rather than by numerous interests with no concerted plan of action. With this object in view it is my opinion that governmental control and regulation of all water-power developments would greatly reduce the immense amount of waste power, by bringing under its direction not only one development but all such developments in any territory. It would serve judiciously to carry out plans for uniform supply, thereby assuring the most efficient use of the water powers, including under their control projects for irrigation, forest preservation, storage for the prevention of floods, etc.

It is difficult to estimate the annual earning capacity of the energy wasted in floods, and the direct damage done by them. The proper storing of water will not only permit of development at the site of the dams but will also increase the power of every user down-stream. With well-designed storage systems it would be possible to more than double the horse power available without storage.

The relation of forests to water-power development is of great importance in the uniformity of flow. In Europe large sums of money are spent to forestize large tracts of land and, in recent years, water-power developments have been encouraged and assisted.

It is only by such a system of intelligent government control that advantage can be taken of all the conditions which go to obtain the maximum amount of energy from the available sources.

O. S. Lyford, Jr. (by letter): Engineers are looked upon as experts in money saving, but seldom as authorities on methods of money getting. Market development, contract making, conservation of earnings, and other strictly commercial problems are seldom discussed by this Institute. Most of our attention is given to the creation of facilities for existing enterprises, but in the field of electric railroading, power development, and other public service utilities, as well as occasional industrial enterprises dependent upon electric power or electric processes, the electrical engineer is being called upon more and more to extend the scope of his investigations and include commercial as well as constructive and operative matters. This requires a thorough knowledge of the essential elements of existing business of the kind under consideration, and ability to form a clear conception of the problems affecting the sales, costs, capital charges, net profits, and even the strategy involved in putting the new enterprise in its proper place in the world's business.

In the matter of costs the engineer must be able to foretell, within reasonable limits, not only the construction cost over which he may have more or less control, but the expense of organization, financing, legal work, interest during construction, etc., which are outside of the sphere of engineering. The fundamental question is: "what will be the return on the investment." The "return" is the net profit dependent upon astute management, as well as the potentiality of the market; the "investment" includes all the money spent in getting the enterprise on an earning basis.

One unfortunate feature of this branch of engineering is that there is never money enough in advance of construction to pay for an extended study of the local conditions. The promoter of a new enterprise faces the prospect of losing all the time and money he puts into it, in the event that the construction funds are not underwritten. In consequence, he allows only a few days for engineerng investigations and restricts the expenditure to a nominal sum. The result, as shown in many of the engineering reports presented to financiers, is an insufficient grasp of the essential facts and improper conclusions as to the warrant of the project. The colossal commercial mistakes in water-power developments in the last few years indicate that even the largest enterprises are subject to the risks involved in this lack of digestion of the governing conditions.

It is obvious that the responsibilities involved in engineering of this character require that only engineers with thorough knowledge of the construction and operation of such properties should be employed. This Institute should aid in the development of this knowledge by giving its members the benefit of as much experience of this character as possible.

Referring to the various subjects suggested in Mr. Doherty's paper, the following comments are submitted:

Interruptions and penalties. The striking feature of the plan of "penalties and insurance" is that it starts out with the statement that "the central station company is not desirous of collecting any penalties," and yet the result of what must have been extended negotiations is the most complex and burdensome method of penalizing the power company which has come within the writer's knowledge. The general theory of the scheme looks reasonable at first, but the practical application is a wide departure from the original proposition.

The apparent intent in this case was to obtain insurance by placing heavy financial burdens on the power company. Penalties are not insurance, however, and even these provisions for operation of the steam plant can be only partially successful in limiting the number and duration of the interruptions, because it is necessary to limit the waste involved in the stand-by losses and therefore the length of time that the steam plant is to be held ready for immediate service.

Thus far the only practical way found to positively insure against power house or trunk line interruptions is with storage batteries large enough to instantly take the load. Aside from the lighting and power systems of heavily congested business centers and a few railroad and industrial plants, this extent of insurance has not been found necessary. For all remaining purposes the service which can be given by a well designed and carefully operated prime mover and transmission system has been found adequate and satisfactory. Where a long distance transmission line is introduced between the prime mover and the consumer, the line is the cause of most of the troubles, but the general experience with *first class* installations throughout the country has been that disturbances due to transmission lines decrease in frequency and magnitude as the system becomes adjusted to the local conditions and the operating force becomes skilled in its duties, so that it is commercially practicable to either depend entirely on the distant power house or at best to have available a relay prime mover plant close to the center of distribution, which plant is not held in readiness to fully and immediately relay the transmitted power, but can be prepared for service in a short time. In some instances the load may be divided between the local steam plant and the distant water power plant so that the overload capacity of the steam plant is available as relay for the water power. This works out commercially only when the load is largely in excess of the water power used.

One great difficulty in attempting to protect the power user against the cost of interruption is that penalties cannot in equity be made to apply in the case of strikes, fires and other major catastrophes without a corresponding provision that the power user shall continue to pay for the power in the event of similar

casualties in his own business. Therefore, these causes are usually excluded from the penalty provisions, except possibly interruptions due to lightning. Inasmuch as interruptions to the service usually occur more frequently because of accidents beyond the control of the power company than because of negligence or inadequacy, it is at once apparent that penalty provisions do not insure.

The art of generating and transmitting power has now reached a state where a user contemplating the purchase of power may predetermine within reasonable limits what degree of continuity of service may be expected from the plant of the company tendering its power. He should first satisfy himself that the power company has the power to deliver and that its plant is complete, first class and up to date (or will be when his service is inaugurated), and that the operating force is adequate to provide the best service practicable for such a plant. He should next satisfy himself that the service possible with such a plant and organization is such that he can afford to become dependent upon it. Unless these conditions obtain, the deal is impracticable at any price, but if they are found satisfactory, the question of price is next in importance and should be determined by comparison with the cost of alternative methods of obtaining power, taking into account the greater or less reliability. Finally it is proper to introduce into the power agreement such conditions as shall insure that the power company's plant and organization are kept up to the highest practicable state of efficiency. Experience has demonstrated that penalty provisions will have this effect, but simple and moderate penalty provisions have been found adequate. It is not practicable to make up in the penalties for any lack in the inherent possibilities of the power company or for a price that is too high.

The writer has been involved in the making of a number of these power contracts, representing in some instances the purchaser and in others the seller. He has in mind four cases of long-term contracts where the penalty imposed upon the power company is either a fixed sum for each interruption or a provision that the power company shall pay to the consumer for the interruption a sum equivalent to twice that which the producer would have paid during the period of the interruption; or that the power company shall pay the cost of temporary operation of the purchaser's plant during the period of interruption or deficiency. In each case there was more or less difficulty between the two organizations during the first months of operation, but the service of the power company improved until the results had been eminently satisfactory to both parties to the agreement.

The making of a long-term contract is often a matter of weeks or months, because each party is trying to anticipate all the contingencies which may develop during the period of the agreement, and it is well for the engineer not to introduce any complex provisions which can be safely avoided.

Verification of engineers' estimates. It is customary to state in the report of a proposed power development the cost of development per horse power or kilowatt of capacity, and if, for instance, the cost is less than $100 per horse power of generator capacity, or $133 per kilowatt, the general impression is that it is a cheap power. In other words, we have become more or less accustomed to put a measure on the feasibility of the development by determining the unit cost on a capacity basis. This has led to false impressions. The writer suggests two factors for convenience in sizing up these enterprises: One that may be called the "Capacity Unit Cost," which is the cost per unit of capacity above referred to. The other may be called the "Output Unit Cost," which is the first cost per kilowatt-hour of estimated possible annual output *deliverable to the customer* in an average year. The annual output to be assumed for the determination of this factor is the maximum which may be delivered at the customer's premises, as limited by the stream flow, the capacity of the equipment and the efficiency of conversion and transmission, assuming a market sufficient to absorb this maximum.

To illustrate the point, the following table is submitted, giving the cost (estimated or actual) of seven separate water powers in the same general district in our Southeastern states, these powers being developed with heads varying from 30 to 120 feet, and with generator capacity varying from 10,000 to 30,000 kw.

A comparison of plant *D* and plant *E* for instance shows that whereas the first cost per kilowatt of generator capacity is in one case $118.13 and in the other $160.14, the output unit cost (first cost per kilowatt-hour deliverable), for primary power only, is lower with plant *E* than with plant *D*. Therefore, unless a large market for secondary power at a good price can be developed, plant *E* is more feasible commercially than plant *D*, in spite of its larger capacity unit cost.

The capacity unit cost of a proposed development may be made to look low by providing an abnormal amount of equipment, but the output unit cost would thereby be raised and the enterprise be thus handicapped. One factor is a check against the other.

The output unit cost is important as giving an immediate measure of the rate at which the power must be sold to make the enterprise commercially practicable. The project will not be attractive to investors unless it promises, within the near future, net earnings at least equal to 10 per cent of the cash cost of development.

Referring to plant *E* in the above table, the output unit cost is 7.15 cents per kilowatt-hour. The minimum net earnings should be, at least, 10 per cent of this, or 0.715 cents per kilowatt-hour. The cost of operation including labor, supplies, maintenance, insurance and taxes for delivering power to the consumers for plants of the size covered by this table varies between 0.1 and

TABLE I

UNIT COSTS OF HYDROELECTRIC DEVELOPMENTS.

Plant	A	B	C	D	E	F	G
Land and water rights	Cash $14.10	cost $12.86	per $8.89	kilowatt $14.20	of $22.22	generator $13.07	capacity. $15.00
Hydraulic construction (dam, canals, flumes, head gates, etc.) } Power house building and substructure }	35.00	43.41	49.50	44.53	51.30	62.42	56.71
Hydraulic equipment	14.00	13.95	13.00	9.05	7.76	7.84	7.56
Power house electrical equipment	21.00	22.73	19.20	13.85	14.50	13.53	12.50
Transmission line, including right of way	17.20	6.26	18.30	9.00	20.70	17.50	28.50
Substation buildings and equipment	5.72	6.51	9.75	7.55	6.82	8.40	8.40
Distribution system	10.00	6.94	4.58	4.45	15.67	14.58	12.00
Interest during construction	6.30	7.36	5.54	4.75	8.40	6.18	6.16
Engineering	5.90		6.14	6.30	7.00	6.87	6.84
General and legal exp.	3.70		6.20	4.45	5.77	7.48	6.84
Capacity unit cost (total cash cost per generator kilowatt	$132.92	$120.02	$141.10	$118.13	$160.14	$157.87	$160.51
Output unit cost (first cost per kilowatt hour of annual output deliverable to customer) Primary	0.0825	0.0717	0.0743	0.0815	0.0715	0.1137	0.0985
Primary and secondary	0.058	0.05	0.0625	0.067	No secondary	0.078	0.0820

0.2 cents; say for this case 0.15 cents. The entire output of this plant (all primary in this case) must be disposed of for an average price of 0.715 plus 0.15 or 0.865 cents per kilowatt-hour, or better, to satisfy the investor. If only half the output can be marketed in the near future, the amount of initial development must be diminished or the average price realized must be twice this figure.

In passing, it is suggested that all estimates of cost of hydroelectric projects be subdivided under the general headings of Table I, in order that convenient comparisons can be made. These headings indicate the general groups which vary independently of each other.

Amount of water it will pay to develop. Mr. Doherty makes the rather startling statement that " the operation of a water turbine for 100 hours per year would in some cases warrant its installation." This must be for very unusual conditions and must relate only to a case where the power can be delivered direct from the turbine to the device driven. In the case of electric generation, transmission and distribution, the investment in hydraulic machinery, generators, transformers and transmission copper varies with the peak load, and it has not been found practicable to provide for service of less than six to eight months duration per annum. The possible condition which Mr. Doherty quotes, however, emphasizes the advisability of considering in each case the provision which should be made for extension of plant to take care of short-term power which may later become commercially practicable.

Under this heading, Mr. Doherty makes the statement that " In this character of developemnt (a hydroelectric development having simply a dam from which the water immediately enters the turbine and is immediately discharged to the river below the dam, without any expensive canals, flumes, etc.), all inequalities of load should be taken care of in the hydraulic plant and if it is necessary to run steam, the steam load should be run for such time, and at such uniform rate, as will secure the most economic generation of steam power."

Usually, the lowest annual cost of operation will not be obtained by operating as Mr. Doherty suggests. It will be found that this will result from generating as few kilowatt-hours per annum with coal as practicable. This will mean a high cost of generation from coal per kilowatt-hour, but this is not the principal feature which concerns the stockholder. With combined coal power and water power equipment, the only items of expense which vary materially with the annual output are coal, maintenance and a part of the labor. The variable elements in the two latter items are small and the principal variable is therefore the coal. As a general proposition, then, the operation which requires the least coal per annum will be found the most economical.

Calculations of depreciation. The writer agrees with Mr.

Doherty that practically all the present assumptions for depreciation on hydroelectric plants are too high. These assumptions, however, usually appear only in the preliminary engineering reports. In the reports of actual operation and earnings they are generally noticeable by their absence. A wrong impression of earning power is often made in the early years of operation of a hydroelectric plant by not providing any sum for depreciation in excess of the actual cost of running repairs. In a recent case under consideration the bankers have proposed that the hydroelectric company set aside each year for maintenance and depreciation a sum equivalent to 10 per cent of the gross earnings from operations, the actual cost of running repairs to be paid out of this fund and the balance to be kept in the treasury as reserve for depreciation. There is no direct relation between depreciation and gross earnings, and therefore no absolute consistency in this plan, but if a depreciation fund is built up on this basis, it will insure against misconception of the earning power of the enterprise, and by being inaugurated in the first years of operation, when the apparatus is new and in good order, an adequate fund will be obtained with a much lower burden on the enterprise than would result from the depreciaton rates usually assumed in advance by the engineers reporting such projects.

In this connection " appreciation " should be taken into account as well as depreciation. The probable increase in the cost of steam power and consequently in the market price for water power is sufficient to counterbalance the elements of depreciation known as " inadequacy " and " obsolescence," so that the only element which need be taken into this consideration is the wear and tear, and possible major accidents due to flood, fire, etc.

Government policy relative to water power developments. In view of the widespread interest in this subject, it may be helpful to the members of the Institute to read into this record the substance of an article published in the " Outlook " of December 4, 1909, in which Mr. Gifford Pinchot outlines the " A, B, C of Conservation." This briefly describes what may be taken as the basis of the policy of the Forestry Service under Mr Pinchot.

Answering the question, " Why is it important to protect the water powers? " Mr. Pinchot states in part as follows:

> It is of the first importance to prevent our water powers from passing into private ownership as they have been doing, because the greatest source of power we know is falling water.* * * Under our form of civilization. if a few men ever succeed in controlling the sources of power, they will eventually control all industry as well. If they succeed in controlling all industry, they will necessarily control the country.

Answering the question, " How must it (the protection of the water powers) be done?" He states as follows:

> The essential things that must be done to protect the water powers for the people are few and simple. First, the granting of water powers forever, either on non-navigable or navigable streams, must absolutely

stop. * * * Water powers must and should be developed mainly by private capital and they must be developed under conditions which make investment in them profitable and safe, but neither profit nor safety requires perpetual rights, as many of the best water power men now freely acknowledge. Second, the men to whom the people grant the right to use water power should pay for what they get.* * *There are other ways in which the public control of water powers must be exercised, but these two are the most important.

Answering the question, "Does the same principle apply to navigable streams as to non-navigable?" the following statement is made:

Every stream is a unit from its source to its mouth, and the people have the same stake in the control of water power in one part of it as in another Under the constitution, the United States exercises direct control over navigable streams. It exercises control over non-navigable and source streams only through its ownership of the lands through which they pass as in the public domain of National Forests.

Summing up the subject, Mr. Pinchot states:

It (the conservation idea) asserts that the people have the right and the duty, and that it is their duty no less than their right, to protect themselves against the uncontrolled monopoly of the natural resources which yield the necessaries of life.

It is not my purpose to discuss this policy in detail, but to show how it works out in a practical application.

The practice of the Government based upon the theory quoted is best illustrated in the form of permit which the Forestry Service is willing to issue. The following extracts are taken from a permit issued in April 1909. These extracts indicate the principal restrictions placed upon the power company:

The gross operation charge for any year shall be calculated by the Forester upon the basis of the quantity of electric energy generated in such year at a maximum rate which shall not exceed the following amounts per thousand kilowatt-hours.

For the 1st year	2 cents
" " 2nd "	4 "
" " 3rd "	6 "
" " 4th "	8 "
" " 5th "	10 "
" " 6th to 10th years inclusive	12½ "
" " 11th " 15th " "	15 "
" " 16th " 20th " "	17½ "
" " 21st " 25th " "	20 "
" " 26th " 30th " "	22½ "
" " 31st " 35th " "	25 "
" " 36th " 40th " "	27½ "
" " 41st " 45th " "	30 "
" " 46th " 50th " "	32½ "

From the gross operation charges for any year, calculated as aforesaid, deduction shall be made as follows:

(*a*) A sum bearing approximately the same ratio to one-half such gross operation charge as the area of unreserved lands and patented lands on the watershed furnishing the water stored, conducted, and/or used in the works for which permit is hereby applied for bears to the total area of the water shed, as of the beginning of each year;

(*b*) A sum bearing approximately the same ratio to one-half such gross operation charge as the length of the conduit, for which permit is hereby applied for, upon unreserved lands and upon patented lands, over which a right of way for ditches and canals is not reserved by the Act of August

30th, 1890 (26 Stat. 391) bears to the total length of such conduit, as of the beginning of each year;

(*c*) A sum bearing approximately the same ratio to the balance remaining after said deductions "*a*" and "*b*" as the quantity of electric energy generated from water stored artificially by the Permittee, over and above what is generated by the natural flow, bears to all electric energy generated.

The Permittee shall, except when prevented by the Act of God or the public enemy or by unavoidable accidents or contingencies, continuously operate for the generation of electric energy the works to be constructed under the permit hereby applied for, in such manner as to generate after such generation begins, not less than the following percentages of the full hydraulic capacity of the said works measured in kilowatt hours: in the first year 33⅓ per cent, in the second year 40 per cent, in the third year 60 per cent, in the fourth year 75 per cent, in the fifth year 80 per cent, and in every year thereafter 100 per cent.

The permit hereby applied for shall cease and be void upon the expiration of fifty years from the date of approval hereof, but it may then be renewed in the discretion of the duly authorized officer or agent of the United States and upon such conditions as he may in his discretion fix, Provided, That such officer or agent, in fixing such conditions, shall consider the actual value at that time for power and all other purposes of the lands and rights of way within National Forests occupied and used under the permit hereby applied for and the actual value at that time of all improvements lawfully made by the Permittee within National Forests under the permit hereby applied for, but neither the property of the Permittee, if any, outside of National Forests, nor the permit, franchises, bonds, capital stock, or other securities of the Permittee shall be considered in fixing such conditions.

There is also the usual anti-trust clause.

In the project to which this permit applies, the tax, if the drainage area and hydraulic conduit were entirely on forest reserve, and if the entire estimated power were marketed, would amount to about $350 for the first year and $5600 for the 50th year. The estimated annual operating cost of the total output of the plant *including fixed charges* is $180,000. Therefore, in such a case an hydroelectric development entirely on forest reserve would, under these terms, be subjected to a tax of from 0.2 per cent to 3.1 per cent of the total annual operating cost. The charge during the first year is not considerable. Whether the charge for the later years will prove reasonable will depend on the taxes and other burdens which may be imposed on the power company by the State.

The principal burden placed upon the power company under this permit is the 50-year limitation, with no definite assurance that the improvements made by the Company will not in effect be confiscated at the end of the period by refusal to renew.

Mr. Pinchot states "Water powers must and should be developed mainly by private capital and they must be developed under conditions which make investment in them profitable and safe." Referring further to Table I, the figures show that the proportion of first cost chargeable to land and water rights is from 6 to 14 per cent of the total cost of the project. In most of the projects which have come to the writer's attention, the conditions would not warrant a price on the land materially in excess of 10 per cent of the total cost. Therefore, in the case

of a power development on Government reserve, in the neighborhood of nine-tenths of the value of the development will be outside of the rights conveyed by the Government. If the present general policy of the Forestry Service is to continue, it is proper that this large proportion of the total cost be protected either by definite provisions for renewals of the license for a similar period or periods, or a provision that the Government may at its option take over the property at an appraised valuation. Without such provisions water powers on Government reserve will not be as attractive as powers on private lands, and it would seem that the general spirit of the conservation idea should result in making the project on the Government reserve the most attractive.

D. S. Jacobus (by letter): The author should be congratulated on preparing a most useful paper, as it is one which deals ably with the subject and at the same time is written with the evident intent of bringing out the ideas of others.

The opinion is advanced that in case a steam plant is used in connection with a water-power plant, as a protection against interruptions, "the internally-fired boiler deserves careful consideration." All available types of apparatus should be considered in the design of a power plant, and the one which is best adapted for the particular conditions should be chosen; in the case at hand, however, the water-tube boiler is so particularly well adapted to the work that, were it not for the desire to bring out discussion, it would seem unnecessary to call special attention to the internally-fired boiler.

In auxiliary steam plants that are held in reserve, all the boilers are not ordinarily kept under steam. The ability to raise steam quickly, starting with cold boilers, is, therefore, an all-important item in this class of work. That there shall be but little stand-by loss in a boiler when held under pressure is also important, and, as the author has pointed out in his paper, this must be considered along with the ability of the boiler to raise steam quickly.

The water-tube boiler is universally acknowledged to be the type which is best adapted for raising steam quickly, and in well-designed boilers of this class the stand-by loss under practical conditions of service will not be greater than that which exists in internally-fired boilers, especially when the water-tube boiler settings are encased in metal to prevent loss due to air leakage. Tests with oil-fuel have shown that with large water-tube boilers the loss from this cause is much less than it is ordinarily supposed to be, as only two per cent of the oil required to run the boilers at their rated power is consumed in maintaining the full steam pressure.

With either coal or oil-fuel and a proper furnace arrangement, steam may be raised, starting with a cold water-tube boiler, up to a pressure of say 200 lb. per square inch in less than half an hour. In fact, in a test where a forced draft was available, and

where a coal fire was started with wood on a bare grate, steam was raised to 200 lb. in 12.5 min. after lighting the fire, the temperature of the boiler and the contained water at the start being 72 degrees fahr. If one should attempt to do this with an internally-fired boiler he would surely come to grief, as leakage would result through excessive strains. A water-tube boiler also responds quickly in starting up from a banked fire, especially if a forced blast is available.

In cases where auxiliary steam plants are used to assist in carrying daily peak loads, it may pay to shut down the water power for a portion of the day so as to give the steam plant a more favorable load-curve. There is no better means of storing power than by collecting water behind a dam, and where this can be done it is often best to operate the water wheels at their maximum capacity during the peak loads, and to shut them down during the lighter loads. A way of obtaining continuous service, as pointed out by the author, is to combine a system of several water and steam power plants, and when this is done much can be accomplished in securing economy by making a careful study of the distribution of the load between the stations. The result of experience indicates that auxiliary steam plants in such a system must be run under a load which varies considerably throughout the day, and, furthermore, there is usually a lay-over period of four hours or more when the steam plants are shut down completely. Under these conditions the water-tube boiler is especially applicable, as the fires need not be started up after the lay-over period until a comparatively short time before the engine is started, the number of boilers in service may be reduced to that actually necessary to carry the load as an additional boiler may be quickly cut into the line in case of necessity, and the boilers will readily respond to a high overload capacity.

There is no boiler as flexible in regard to operating conditions as a water-tube boiler, and while it may be run economically at a low rate of evaporation, it may also be run with but little falling off in economy with as high a rate of evaporation as eight or even more pounds of water per hour per square foot of heating surface. In fact, the capacity of a well-designed and properly proportioned water-tube boiler depends simply on the amount of coal that can be burned beneath it, and modern practice is leaning more and more toward running such boilers at high capacities for peak loads, and also for intermittent service of the class herein discussed, because when considered as a whole the economy of the entire plant, including items of capital investment, etc., is better than that secured by running a greater number of boilers at a lower rating.

Ralph D. Mershon (by letter): I quite agree with Mr. Doherty as to the value of water-power securities and as to the probable great increase in their value with the course of time. This increase in value will come about partly through increased fuel

cost; partly through the increase in available power of existing plants, due to pondage, as other powers or storage reservoirs are built on the same stream; partly through the institution of new industries which will not install heat-engine power plants and will, therefore, be able to pay a higher price for power than if they already had such power plants; partly through the greater use of off-peak power, either by rearrangement of the hours of operation of industries or by the perfecting of electrochemical processes operative intermittently; and partly through utilization of flood water power by intermittently operative electrochemical processes.

The author speaks of water power being developed under the direction of State and Federal governments and hints even at governmental financial aid to insure full, economic development of the capabilities of streams.

There are few amongst us, I think, in favor of giving to private enterprises absolute title to water power rights on the public domain. If Mr. Doherty had given us a paper devoted entirely to the consideration of the methods and means whereby such aid as that he suggests and hints at could be given without unduly favoring private enterprise, and whereby the ultimate title to water power sites on public domain could be secured to the people as a whole, he would have done a work of much greater value, in my opinion, than he has in this more general and less definite paper, valuable as it is. In fact, the adequate treatment of this one phase of water power development is perhaps more immediately important than that of all the other points he mentions; certainly than that of any one of the other points mentioned.

A carefully worked out scheme which would successfully apply to water powers the suggestion he makes, would apply with little, or obvious, change to other things as well. And one of the greatest problems before this country to-day is to devise schemes which will steer the middle course between socialism and monopoly; schemes which while preserving to the people some proper measure of the unearned increment, will yet allow sufficient profit to the investor to attract capital. I shall revert to this matter later.

Mr. Doherty speaks of the frequency with which estimates have been exceeded and the fact that the blame is usually laid upon the estimating engineer. The estimating engineer is a very convenient scapegoat. It is far from the case that the fault is always his. He estimates under reasonably favorable assumptions, or even under assumptions reasonably unfavorable, but assumes, as he has a perfect right to do, that the construction will be wisely administered. What is the result? The work is often handled either by a number of people in general and no one in particular, or by someone who has achieved fame and fortune running a bank or a pie bakery, and who is, therefore, because of such fame or fortune, assumed to be fully competent to cope with

any other enterprise, however widely different from that in which he achieved success; someone who has about as much idea of the proper handling of a power enterprise as the wards of the Prodigal Son had of heaven. The estimates are exceeded and then—it is the fault of the estimating engineer!

In order that such enterprises shall be successful, some *one* must walk the floor with them. And that someone must be something more than a wet-nurse; must be a doctor, or at least know when to call the doctor in, and to call him in time.

Then there is administration by a board of engineers; from which the Lord deliver us! The petty jealousy which will sometimes animate a board of engineers and lead to unwise compromises because of pure stubbornness or vanity, is amazing. I would rather trust my financial fate, if I ever have any, to one man (and to him absolutely) who is honest, has good judgment and the engineering instinct, than the best board of the best engineering specialties every gotten together. He may make some mistakes, who does not?—but what he will save in other directions will much more than pay for any mistakes he is likely to make.

If he has the engineering instinct he will recognize the important and vital problems when they arise. If he is honest he will, if he has the least doubt of the entire adequacy of his own ability to solve them (and even, perhaps, if not in such doubt) call for the services of the best specialists in their solution. If he is wise, he will apply his wisdom in utilizing the findings of these specialists—or in discarding them altogether.

The author speaks of the fact that a good enterprise may go begging because of a conservative prospectus, where a less meritorious one is financed because of the glittering prospects outlined. This condition is not limited to the relation between the financier and the public. It obtains at times as between the financial man and the engineer. And the engineer who promises the greatest returns for the least money and will sign his name to a report setting forth such, will often get engineering work where the man with less imagination (and shall we say with higher ideas of honor?) is passed by. The latter may glean some grains of comfort of a certain sort, later, when the enterprise gets into trouble, but this is poor consolation if a meritorious proposition in which he is interested is rejected because of the distrust bred of the other failure.

This is human nature. If the shoe dealer on one side of the street states honestly just what his shoes will do, and the one on the other side lies about the shoes he sells at the same price, most of us will buy from the man we suspect to be a liar, because we know the honest man's shoes cannot possibly turn out any better than he claims, while there is a chance that the liar will make good.

An engineer's estimate and report should be made in that frame of mind which would obtain if he were going to put his

own real money into the enterprise. Indeed, where it is possible, it were well for all concerned, including the engineer, if he had a relatively large " stake " in the enterprise; provided he is not to be crucified by the administration of the pie baker aforesaid.

Mr. Doherty's attitude and, generally, that of those discussing his paper, is, I think, unduly severe on the service from transmission lines. There are hydroelectric transmission plants in existence giving as reliable service as is obtained from steam plants, and there will undoubtedly be more of them as time goes on. Of course an overhead transmission line cannot be made immune to interruption, except at a prohibitive cost. And no matter what expense might be gone to, there would always be the possibility of malicious interference. Generally, whatever can happen will happen, if it has enough chances to happen; which applies to steam central stations as well as to hydroelectric transmission plants.

In the matter of rates, Mr. Doherty seems to be somewhat inconsistent, which inconsistency is partially revealed in his assent to the implied criticism of Mr. Ryerson's remarks anent the sale of off-peak power.

As I see it, there are two ruling propositions implied in Mr. Doherty's remarks on rates; which are as follows:

(1) It is fair that the supplying company should have the full advantage of non-coincidence of peaks; that it should not share this advantage with the consumer.

(2) It is fair to base the charge to the consumer on the cost to him of supplying himself from his own plant.

It seems to me that in the ultimate analysis, the whole thing hinges on (2). For instance, (1) goes to pieces immediately we apply the extreme case of non-coincidence of peaks cited by Mr. Ryerson; that is, the sale of off-peak power. In such case, Mr. Doherty is in favor of dividing some of the advantages with the consumer; and in making concessions in such case, I think it a safe wager he would be guided as to the amount of the concession by what the service would cost from the customer's own plant. I do not advance this as a destructive criticism of Mr. Doherty's well known method of charging, but simply to emphasize the fact that these seemingly fundamentally and inexorably sound schemes of charging are not necessarily so universally sound as they may appear at first sight. And indeed, when so surprising a condition arises as that cited by Mr. Doherty, where the investment and maintenance charges for meters alone exceeds that of the generating equipment to supply them, one is inclined to ask whether in such case it would not usually be better to again throw to the winds the fundamental charging scheme and supply these customers on some flat rate basis; with some cheap device for limiting their maximum demand.

The author regrets the confusion of terms, especially in the minds of the public, and speaks of the desirability of standardizing terms and endeavoring to educate the public to a clearer

understanding of their significance. In this I entirely agree with him, though his paper itself is not entirely above criticism in this regard. A large part of the difficulty has arisen from the employment of the term *power* where really *energy* is meant. Usage has made this so universal that it would be hopeless to try to change it now. But strictly speaking, it is no more correct to speak of selling or transmitting power than it is to say that the distance from New York to Chicago is fifty miles per hour.

And it is not the layman only who has confused ideas on this subject. Not long ago, I saw a power contract, drawn by engineers, in which great pains had been taken as to exact expression. It reached the heights of exactness in a paragraph which read about as follows:

> Wherever, herein, the term energy is used, it is meant to signify energy measured in horse power or kilowatts.

Energy in horse power or kilowatts!!!

In his oral reply to the discussion, Mr. Doherty speaks of the practice, so called, of "watering stock." I quite agree with his remarks on the subject. We cannot expect capital to go into enterprises involving a certain amount of risk if the returns therefrom are to be no greater than could be obtained by loaning the same amount of money on security involving a risk much less than that of the enterprise. There must be a profit over and above such returns. I know of no cleaner cut or better way, *provided it is not abused*, of distributing in advance of its realization, the equity in such profit, than by the issue of profit stock. I say *provided it is not abused*, because in the past it undoubtedly has, in some cases, been very much abused by methods savoring of those of the bunco steerer or confidence man. If we could have such laws as would insure the issue at regular intervals of correct, intelligible statements of the results being achieved by corporate enterprises, so that there could be no deception as to the value of the profit stock, the public would at least have the opportunity for independently arriving at a decision as to what this stock was probably worth, and would have some chance for self-protection.

The amount of self-protection possible even under these conditions would depend upon the ability of the public to judge as to the value, or probable value, of the securities. This leads up to another subject, namely that of the ignorance on the part of the public of even the simplest questions of finance. I venture to say that not 10 per cent of the business men of this country, not 10 per cent, even, of the men who are independently conducting business on their own responsibility, could give an intelligent explanation of, for instance, the difference between first mortgage bonds and common stock.

This deficiency is not confined to the public. The engineer, who ought to know something about such matters, is often woefully ignorant. The study of this subject should be made a part of every engineering course, and I am glad to know that

some engineering schools are now giving instruction in the rudiments of finance.

In fact, my ideas in connection with this matter go a good deal further. It seems to me it would be well if instruction along these lines were given in every high school, so that the average citizen might have a clearer idea of these matters. I believe that, if he had, he would be much more likely to take an interest in the various creative enterprises arising from time to time (instead of putting his money in a savings bank) thereby acquiring some portion, at least, of his share of the unearned increment; which would result in staving off and modifying, if not forever dissipating, the socialistic influences we are now beginning to feel.

As I have said before, I believe Mr. Doherty could have done us even more good than he has in his paper if, instead of it, he had presented a paper dealing with the possible methods of developing the water powers on the public domain in such a way as would, while attracting capital, secure to the public the titles to them, and at least a portion of the benefits from them. I believe he owes it to himself and this Institute to write such a paper; that there is no more patriotic or philanthropic thing that he could do at the present time.

There are a number of methods which might be devised for arriving at the end suggested. Some occurring to me are as follows:

(1) The water powers might be developed by the Federal or the State governments.

(2) They might be developed by private individuals under the supervision of the Government and with funds supplied by the Government.

(3) They might be developed by private individuals under the supervision of the Government, by the proceeds of bonds guaranteed by the Government.

(4) They might be developed by private enterprise, under the supervision of the Government, with funds raised by the private individuals and with the provision that after a certain period, the Government might take over the property created, at a price either fixed beforehand or to be determined by arbitration.

In no case, however, should they be operated by the Government, but in all cases supervised by the Government to an extent to insure proper maintenance. In the case of (1), (2), and (3), the Government might lease the plants, the lease to be made as the result of bids, contemplating either a compensation to be paid to the Government over and above the interest on the investment, or fixing the price at which power shall be sold, or both. In the case of (4), and perhaps of (3), the operation would presumably be in the hands of those constructing the plant, to be open again for competitive bids at the end of the period of such occupancy.

I myself should be rather inclined to some such scheme as (1), (2), or (3), since it would put a premium on brains rather

than on money and give an opportunity for men having no capital, but recognized standing as to efficiency and ability, to go in and on their own initiative develop the property and its market, securing a handsome return in the process.

The above suggestions are made merely as tentative suggestions and not even as carefully considered ones. In fact, one of the controlling motives in making them is that they may stimulate the fertile brain of my friend Mr. Doherty, by arousing his antagonism or otherwise, induce him to write for the High-Tension Transmission Committee the paper I have suggested, and thus lead to more carefully worked out suggestions for arriving at the desired end.

[Mr. Doherty's closure to the written discussions on his paper will appear in a subsequent issue of the PROCEEDINGS.—Editor.]

NOTE

The following paper is to be read at the regular meeting of the American Institute of Electrical Engineers in **New York City, February 11, 1910.** This meeting is to be held under the auspices of the Telegraphy and Telephony Committee of the Institute. All members of the Institute are invited to be present and participate in the discussion of the paper.

Written contributions will be read at the meeting for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of the contributors.

The object of issuing the paper in advance of the meeting is to increase the interest and authority of the discussion by affording those desiring to participate a longer time for the study of the paper and the preparation of their views.

Those desiring to contribute to the discussion of this paper, either orally or by letter, should notify **William Maver, Jr., Chairman Telegraphy and Telephony Committee, 136 Liberty Street, New York** not later than February 9, 1910. Written contributions should be in his hands by that date.

A paper to be presented at the 243d meeting of the American Institute of Electrical Engineers, New York, February 11, 1910.

(Subject to final revision for the Transactions.)

A MODERN AUTOMATIC TELEPHONE APPARATUS

BY W. LEE CAMPBELL

The writer presented a paper before the annual convention of the Institute in 1908, dealing with automatic telephone equipment from an economic viewpoint.* The present paper will therefore be principally devoted to a description of the apparatus used and its method of operation in modern plants. Although there are several different types of automatic telephone equipment upon the market or being developed, practically all of the working plants use apparatus of the " Strowger " type with or without the addition of Keith line switches. Since this paper must be confined to one system, only the one which is extensively used will be discussed. The description will begin with a short reference to the subscriber's station equipment.

Prior to the year 1896, an automatic telephone subscriber called any number which he might desire by pressing push-buttons on his telephone. There were generally three push-buttons arranged and labeled as shown in Fig. 1. If the subscriber wished to call No. **143**, for example, he would first push the " hundreds " button once, then the " tens " button four times, and finally the " units " button three times. While this arrangement gave passable service, the subscribers made many mistakes in counting the pushes and sometimes did not press a button in far enough or hold it in long enough. Consequently, in 1896, a button-pushing machine or a " calling device ", as it is commonly named, was substituted for the push-buttons. A modern wall telephone equipped with a calling device is shown in Fig. 2 and a modern desk telephone in Fig. 3.

* A Study of Multioffice Automatic Switchboard Telephone Systems, TRANSACTIONS A. I. E. E., 1908, p. 503.

As shown in these Figs. the visible portion of the calling device consists of a dial pivoted at its center so that it may be turned in a clockwise direction. For convenience in turning it has finger holes eleven in number around its outer edge. Through each finger hole, except the eleventh one, a number is seen. These numbers are consecutive from **1** to **9** and back of the tenth finger hole **0** appears. In automatic practice **0** always represents 10.

To call **143**, for example, a subscriber will first put his finger into the hole through which number **1** is seen and pull the dial around until his finger strikes the stop. He will then take out his finger and place it in the hole through which **4** is seen and again pull the dial around until his finger strikes the stop. Finally he will place his finger in the hole through which number **3** is visible and turn the dial till his finger again strikes the stop. He then places the receiver to his ear and awaits the

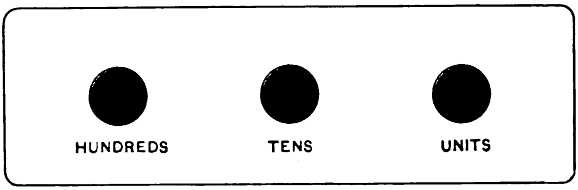

FIG. 1

answer of the party called. Each turn of the dial requires approximately one second, and by the time he has placed the receiver to his ear the automatic machines at central office will have completed the connection to the desired line and will be automatically ringing the bells of the desired telephone. When through talking, he hangs the receiver on the switch-hook and the break in the talking circuit thus made causes the central office apparatus to return to normal condition.

There is contained within the calling device, but not seen, a revolving cam arranged to make and break the contact between a pair of springs. An escapement geared to a small governor controls the speed at which the cam revolves. The power is furnished by a clock-spring which is rewound each time the subscriber turns the dial. The cam does its work after the subscriber's finger strikes the stop and while he is placing his finger in the next hole. If he tries to turn the dial before the

cam rotation is finished, he finds it locked. It stays locked until the cam rotation is completed.

The principles involved in the operation of the dial are carefully worked out and are essential to rapid and accurate calling; the finger is each time placed in a stationary hole in front of a stationary number and is then moved until its strikes a stop. Every movement is positive and accurate, regardless of the speed at which it is made. Any one who has experienced the slow and painstaking care required to manipulate the dial on an ordinary office safe to bring each successive number opposite the stopping point without first passing it, will readily appreciate that any calling device which would require the subscriber to stop each number opposite a pointer or, vice-versa, to stop a pointer

FIG. 2

opposite each number, would be very slow and inaccurate in comparison with a calling device like that shown in the illustrations.

If the number called by a subscriber is " busy ", his receiver will give forth an intermittent buzzing sound, the same as that used for a busy signal in large manual systems.

If the number he calls is that of a former subscriber, or of a subscriber whose number has been changed, he will be automatically switched to the information operator, who will give him the information most suitable under the circumstances.

If a " long-distance " connection is desired, the subscriber turns his dial once from the 0 finger hole, which is labeled " Long-Distance " also. He is thereby connected directly to the re-

cording operator of the long-distance board, who takes his order just as in manual practice and then informs him that she will call him when she has his party. When the long-distance connection has been put up, the operator calls the subscriber and the conversation proceeds in the usual way.

Each automatic system is generally equipped with an information and a complaint desk, each of which is presided over by an operator who supplies needed information to inquiring patrons, or records their complaints.

Extension telephones, coin-in-the-slot telephones, party lines, inter-communicating systems, and private branch-exchanges are all worked satisfactorily at the subscriber's stations.

FIG. 3

A subscriber's private branch switchboard may be either of the well known manual type presided over by an operator—who makes the local connections and who supervises all of the calls to and from the public exchange—or it may be automatic with all subscribers' stations equipped with automatic telephones so that they may call each other or call public exchange patrons by means of their automatic calling devices without the aid of an operator, or it may be a combination of the two with the local calls automatic and those to and from the public exchange supervised.

It is perhaps needless to say that the transmitter, receiver,

ringer, and hook-switch for an automatic telephone may be of any standard type. The only part of the instrument that is peculiar to the automatic system is the calling device. In fact an ordinary common-battery manual telephone may readily be adapted for automatic service by mounting the calling device upon it as shown in Fig. 4.

Turning from the discussion of the subscriber's station to the central office equipment, the machines which make the connections between subscribers' lines are divided into the following classes:

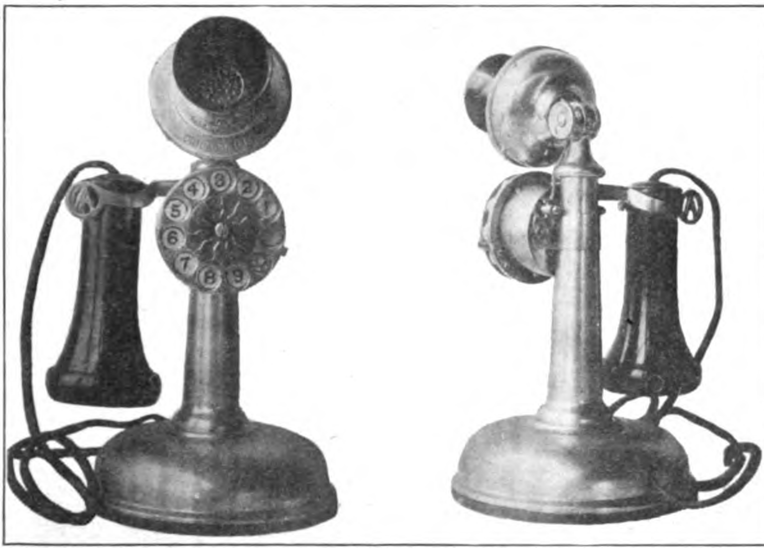

FIG. 4

1. Line switches.
2. Selector switches.
3. Connector switches.

A connector switch commonly called a "connector", is the last one operated in completing each connection; but as its functions correspond most closely to those of an operator on a manual switchboard it will be considered first.

There are two principal differences between the work of an operator on a multiple switchboard and that of an automatic connector. The first lies in the difference in the number of lines to which they have access. The operator has within her reach a multiple jack for every line in the switchboard, be the number

of lines 1000 or 10,000. She may therefore make a connection *to* any line entering the office, but a connector switch has access to but 100 lines. Secondly, a subscriber's operator takes the orders of and makes connections *for* certain predetermined subscribers only. The number she serves seldom exceeds 200 and is often less than 100, but a connector switch is, when idle, ready

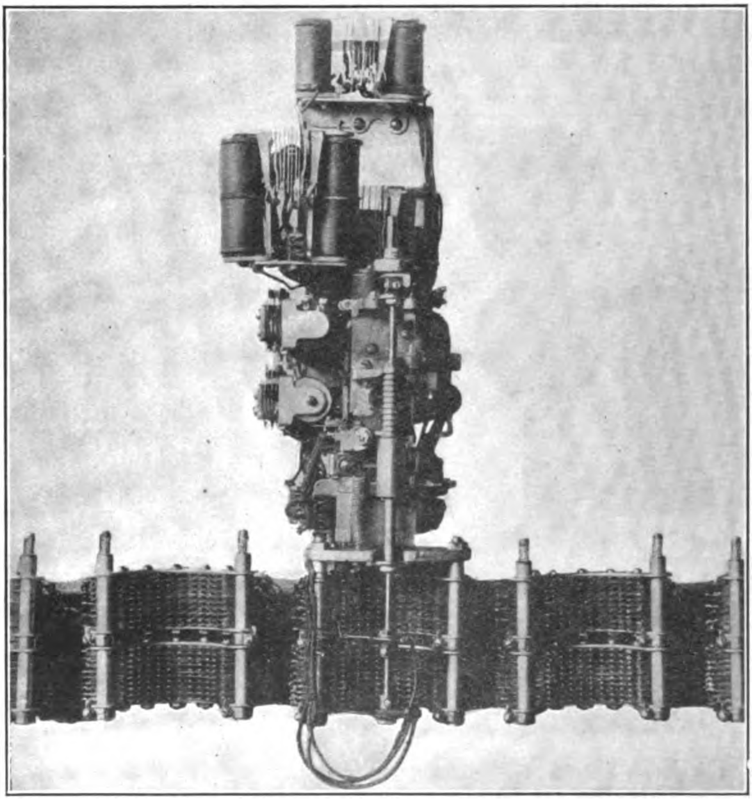

Fig. 5

to handle the order of any subscriber who may wish to connect to any one of the 100 lines to which it has access.

A picture of a connector switch is shown in Fig. 5. The lower part of the machine supports two curved banks of contact plates or strips. The under bank, called the line bank, contains 100 pairs of these contact plates arranged in 10 horizontal rows, 10 pairs to the row. See left hand bank, Fig. 6. These pairs

of bank contacts correspond to the line springs in the multiple jacks of a manual board, and, as pictured in Fig. 5, may be multipled before any desired number of connector switches. The upper bank contains 100 single contacts which correspond to the rings of multiple jacks. This is the busy-test bank, commonly called the "private" bank. The cord and plug of the manual board are represented by the "wipers" on the shaft of the machine. The lower or line wiper consists, as shown more clearly in Fig. 7, of a pair of long flexible springs insulated from each other and each soldered to a flexible cord, while the upper or private wiper is a pair of springs connected together to a third cord. The movements of the wipers, corresponding to those of an operator raising a plug and inserting it into the proper multiple jack, are performed by the shaft which has a step-by-step vertical movement and a step-by-step rotary movement.

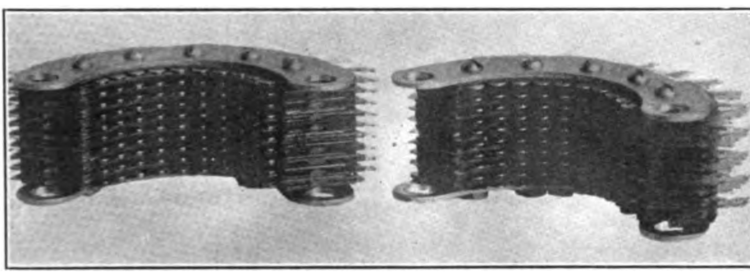

FIG. 6

These movements are actuated by pawls and ratchets operated by electromagnets controlled by the subscriber from the calling device on his telephone, and are always in accordance with the last two digits of the number he calls. For example, if he calls a number ending in **43**, the shaft is raised four steps and then rotated three steps, thus raising each wiper opposite the fourth row of contacts from the bottom of its respective bank and then sliding it over to the third contact in the row. The machine is then ready to close the circuit of the calling subscriber through to the circuit of the called party, but before doing this it first closes the private wiper-circuit only and thus makes an automatic busy test. If it finds the desired line busy, it keeps the connection open and immediately transmits the busy signal back to the calling subscriber. If the desired line is not engaged, the connector switch immediately begins to ring the called

party's telephone bell automatically and intermittently. When he answers, the ringing stops and the two subscribers lines are closed together for conversation. Talking current is supplied to the transmitters of both telephones from the central office battery through the relay coils of this connector switch, just as

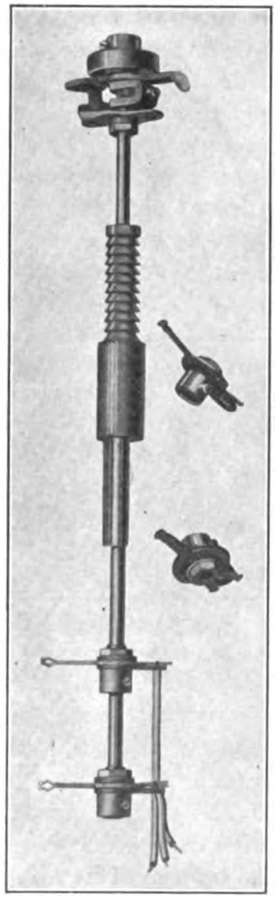

FIG. 7

in manual practice it is supplied through the relay coils of the cord circuit. The talking circuit includes nothing but these coils and the subscribers' stations. Its simplicity and perfect balance are shown by the circuit in Fig. 8.

When the subscriber's conversation is completed and the calling party restores his receiver to the switch-hook, the shaft of

this connector switch is " released " and is immediately returned to normal position by means of a clock-spring and gravity. It is now ready to handle another connection for any subscriber in the plant.

One such switch cannot, of course, handle all calls to the 100 lines to which it has access. In the average plant, 10 connectors are sufficient, however, for each 100 lines, because ordinarily not more than 10 subscribers in any hundred are ever receiving calls simultaneously. Consequently a system of 10,000 lines, for example, is divided into 100 groups of 100 lines each, the calls to the subscribers in each group being completed by a set or multiple of 10 connector switches. Where it is found necessary, more than 10 connectors may be put in a multiple; where expedient, economy is attained by putting in less than 10. Uniformity is desirable, however, and it is therefore good practice—although it is not general practice—to exercise some care in arranging the subscribers' numbers, so that each group of

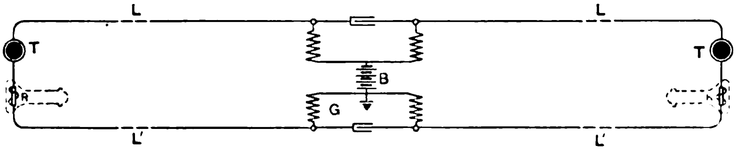

FIG. 8

100 will contain approximately the same proportion of frequently used lines to lines that are used less often. The grouping of lines is strictly according to number; that is, all lines numbered from 2100 to 2199 are put into one group and connected to by one set of connectors, while all lines from 2200 to 2299 are put into another group, etc. It will now be understood that a calling party, to complete a connection to a desired line, must first obtain connection to an idle connector switch belonging to the group or multiple in which the desired line terminates. In other words, processes of group selection and of idle switch selection are performed by other switches which do their work before the connector switch is operated.

These switches, which are called selector switches, have already been mentioned. A picture of a selector switch is shown in Fig. 9. It looks, and is, very much like a connector switch; in fact the mechanism and banks are the same. The differences are in the circuits and relays only. In a system of 10,000 lines,

these selectors are divided into two classes; namely, first selectors and second selectors. While there is a group of connector switches for each 100 lines to which connections are to be made, there is a group or multiple of second selectors for each 1000 lines to which connections are to be made, and a group or multiple of first selectors for each 10,000 lines to which connections are to be made. The bank contacts of the selector switches are terminals of trunk lines instead of sub-

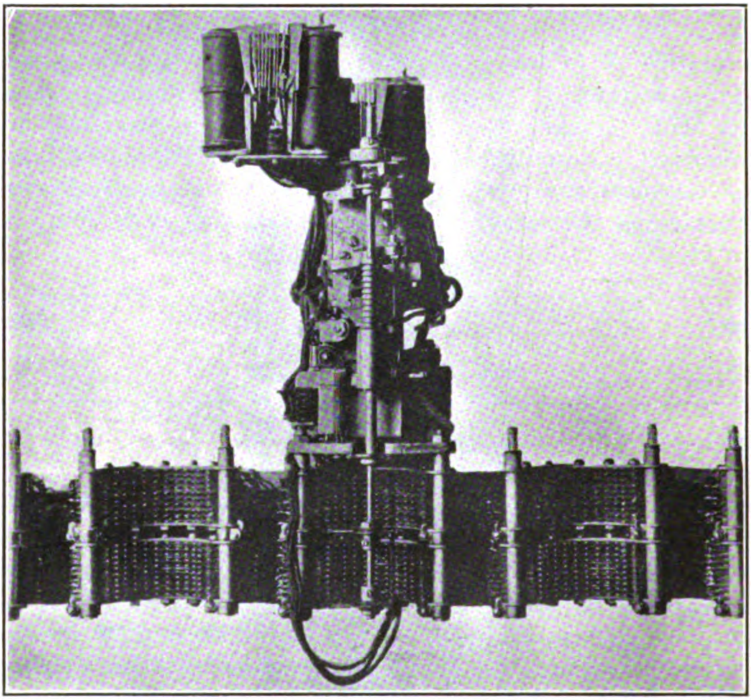

FIG. 9

scribers' lines. The first or lower row of first-selector bank contacts constitutes the terminals for a group of 10 trunk lines leading to second-selector switches in the **1000** section of the plant. The second row represents another group of 10 trunk lines to second selectors in the **2000** section of the plant, the third row represents a group of trunks leading to second selectors in the **3000** section of the plant, etc., so that through the 10 rows of bank contacts the first selector has access to 10 second se-

lectors in each of the 10 sections of 1000 lines which make up a 10,000-line office. The first selector switch used by a calling subscriber is operated in accordance with the first digit of the number he calls. Suppose, for example, he is calling the number **2543**. The impulses sent in by the first movement of his calling device will raise the shaft, and accordingly the wipers of the first selector switch two steps, placing each wiper opposite the row of bank contacts second from the bottom in its respective bank. Now the selector switch unlike a connector switch, does not wait for the subscriber to make another turn of his dial before rotating its shaft, but the rotation is automatic and beyond the subscriber's control.

The rotation starts the instant the vertical movement is completed, and, in the particular case which is here used as an example, sweeps the wipers step-by-step over the row of bank contacts connected to trunks leading to the **2000** section. At each step of the rotation the bank contacts on which the wipers then rest are given the busy test, and as soon as a disengaged trunk line is found the rotary movement stops and the connection is completed to an idle second selector. This is all accomplished in a fraction of a second, so that the second selector is operated by the subscriber's calling device impulses corresponding to the second digit, **5**, of the number **2543** which he is calling. The wipers of the second selector are accordingly raised five steps and are then automatically rotated just as the first selector wipers were. The bank contacts of this second selector are the terminals of the trunks to the 10 sets of connectors which complete the connections to the line groups making up the **2000** section of the plant. Consequently when the second selector wipers stop on an idle trunk in the fifth multiple, the calling subscriber is placed in connection with an idle connector in the 2500 groups; that is, a connector which has access to the desired subscriber's line No. **2543**. This connector is then operated by the last two movements of the subscriber's calling device, and performs the functions of an operator in the manner already described at some length.

Fig. 10 is an endeavor to illustrate this grouping arrangement and shows the connection just described from the calling telephone to a first selector, then from the second row of first-selector bank contacts to a second selector in the **2000** section of the exchange, then from the fifth level of this second selector's bank contacts to a connector switch in the **500** group of the **2000** sec-

tion, and then through the fourth row of the bank contacts of this connector to the called telephone.

It is readily understood that by thus using a first selector to pick out a trunk to any one of ten different **1000** sections,

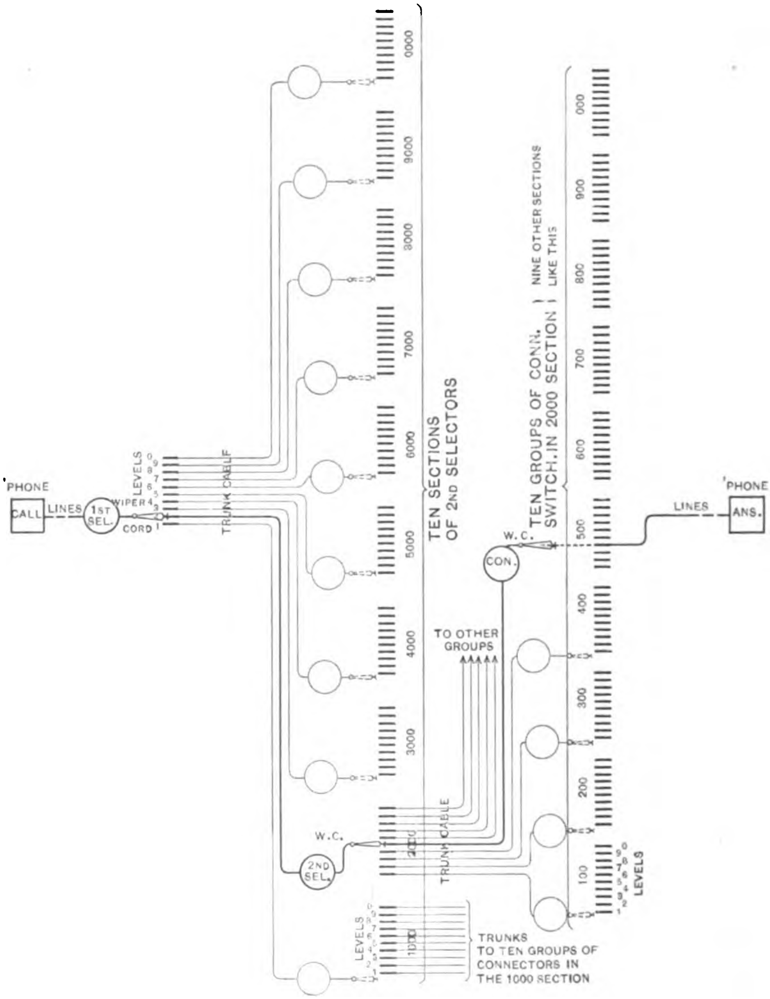

FIG. 10

second selectors in each section to pick out trunks to any **100** group in each **1000**, and then by using the connectors to complete calls to individual lines in each **100**, that connection may be made by the use of three switches from any calling tele-

phone to any number from **0000** to **9999** or in other words to **10,000** different numbers. It will also be readily understood that by using a fourth switch, called a third-selector switch, and using numbers with five digits instead of four, that the capacity of the system will be multiplied by ten and will be 100,000 lines instead of 10,000. In a system of 100,000 lines, **10,000** numbers are generally set aside for each main central office. Consequently on each call the first selector picks a trunk to the desired office, the second selector picks a trunk to the desired **1000** in that office, the third selector picks a trunk to the desired **100** and the connector completes the connection to the desired line.

Systems of 100,000 lines' capacity have been installed in a number of different cities. One of the most notable is that in Los Angeles. This system is illustrated in Fig. 11. As shown, there are six main offices, each with an ultimate capacity of 10,000 lines.

The Olive Street main office is now equipped for 10,000 lines, West for 4000 lines, Adams for 2500 lines, South for 5000 lines, Boyles for 800 lines, and East for 1000 lines. The numbers in the South Office all commence with **20,000**. Those in Olive Street Office all commence with **60,000** etc.

South office has a branch office called Vernon; West office has two branches which are called Prospect Park and Hollywood; East office has a branch called Highland Park. The numbers in each branch office commence with the same digit as the numbers in the main office to which it connects. That is; one of the sections of **1000** numbers are taken from the main office and are set aside for use in the branch. For example: the lines now equipped in South office are numbered from **21,000** to **25,000** and the numbers in its branch Vernon, run from **29,000** to **29,999**. It is, of course, unnecessary for a calling subscriber to know to which office he is connected or to which office the party he desires to call is connected.

The trunking between offices is all automatic. A subscriber, for instance, in the South office, who, on the first move of his dial turns it from the number **2**, will automatically select a local trunk line to a second-selector in South office. If he makes the first turn from the number **3**, a first selector at South office will automatically connect him to a trunk line terminating in a second selector at East office. Or, if he makes the first turn from the number **6**, the first selector at South Office will automatically select an idle trunk to Olive Street office, etc.

Suppose, a subscriber connected to the South office wishes to call **62,127**, which is an Olive Street office number. The first movement of the dial operates a first selector at South office, and extends the connection over an idle trunk to a second selector switch in the Olive Street office. The second digit **2** will operate

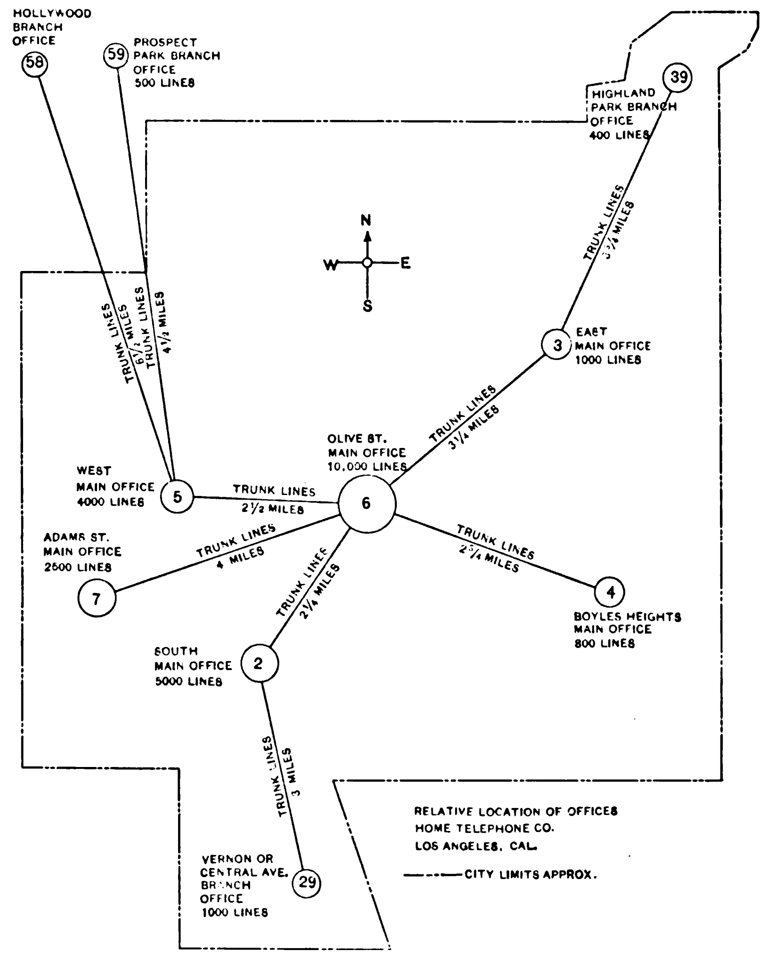

FIG. 11

the second selector at Olive Street office, and extend the connection to a third selector in the **2000** section of the Olive Street switchboard. The third digit **1** will extend the connection to an idle connector switch in the **100** group of the **2000** section. The last two digits will operate this connector switch and complete the connection to **27** in this particular **100**.

Suppose, again, that a South office subscriber is calling **39,143** which is in the Highland Park branch office. The first movement of the dial operates a first selector in the South office and selects a trunk to a second selector in the East Main office. The second movement of the dial raises the shaft of this second selector nine steps, and selects an idle trunk to a third selector in the Highland Park branch office. The third movement extends the connection through a local trunk in the Highland Park branch office, to an idle connector in the **100** group, and the last two motions of the dial result in the completion of the connection to **43** in that particular hundred.

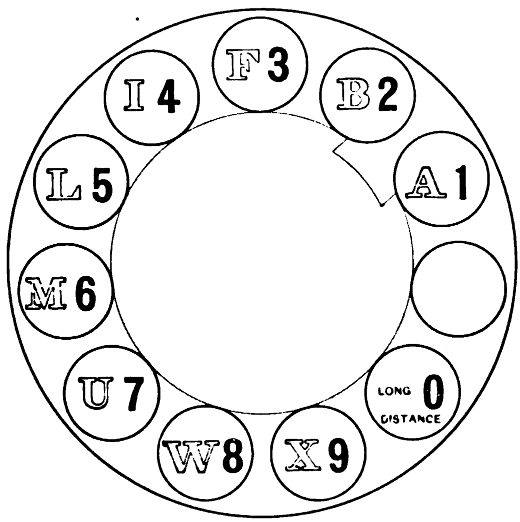

FIG. 12

It is interesting to note that the distance from Vernon office to Highland Park office is over 12 miles, and that the distances between the other offices are quite long. It is therefore apparent that the trunks between switches may be of almost any desired length. It is also to be noted that the time required to complete a connection and the number of machines used is independent of the number of offices through which a connection may be trunked.

It should be said here that in all 100,000-line systems the numbers are made up of a letter and four figures instead of five figures.

Fig. 12 shows a calling-device number disc for a system of this size. Using this arrangement **26,187**, for example, would

appear in the telephone directory as B-**6187**. When operating the calling device many subscribers will remember a letter and four figures more clearly than they will five figures.

It might be inferred from the foregoing portion of this paper that there is one first-selector switch permanently connected to every subscriber's line. Formerly this was the case, but in a modern plant each line terminates in a much smaller and a cheaper device called a line switch. The line switch is not under the control of the subscriber, but connects him automatically

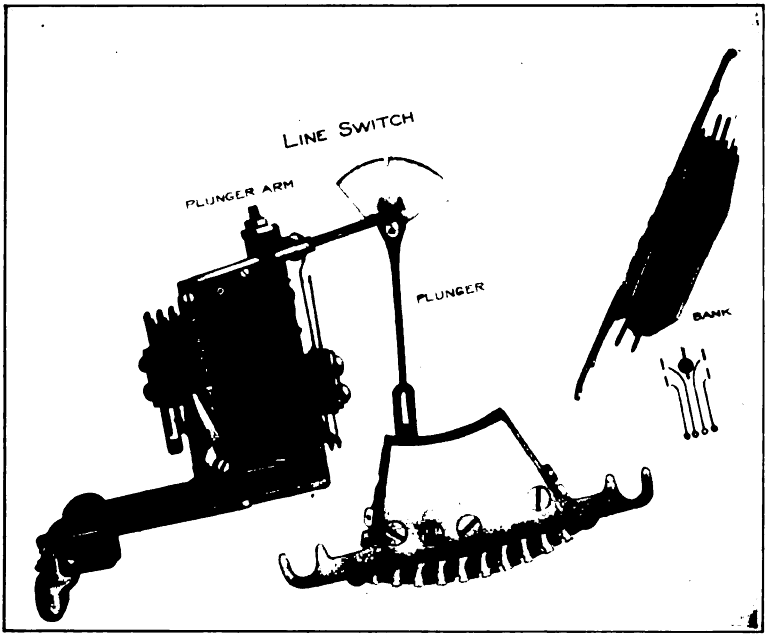

FIG. 13

to an idle first-selector switch the instant he removes his receiver from his switch-hook preparatory to making a call. The first-selector is, therefore, operated by the first impulses transmitted from the subscriber's calling device just as in the older systems. When the line switches are used, 10 first-selectors for each 100 lines are generally sufficient to handle the traffic.

Each line switch, see Fig. 13, includes the line and cut-off relays with which each line is equipped just as in manual practice. It also includes a moveable plunger arm at the end of which a

plunger is so pivoted that it may be swung back and forth over the line-switch bank. The bank consists of 10 sets of springs

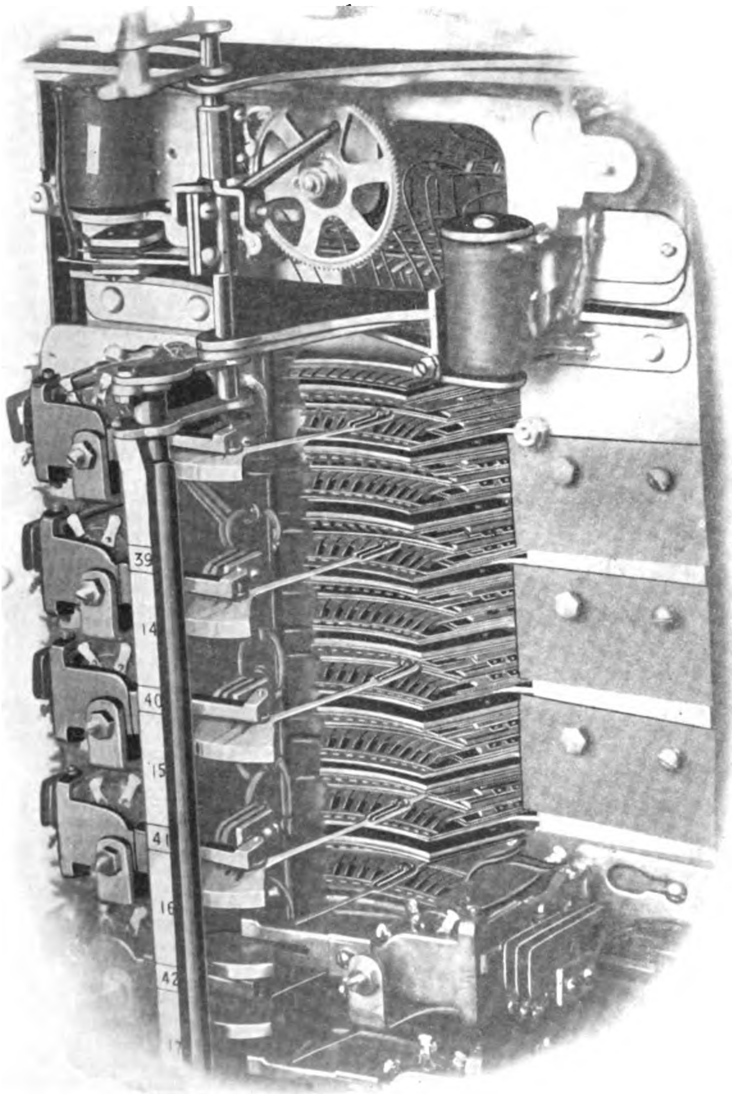

FIG. 14

and represents a multiple of 10 trunks to first-selector switches. The line switches are mounted in groups of 25 each on the face

of an upright in such a manner that the plungers are in alignment. See Figs. 14 and 15. The notch in the head of each plunger meshes with a rocking bar or " master shaft " as it is called. A step-by-step device called a master switch (seen in the upper part of Fig. 14) is connected to each pair or to each four master-shafts and by means of them can swing the plungers back and forth, step-by-step over the banks of contact springs. Normally the plungers are at rest poised over bank contacts multipled to an idle trunk.

When a subscriber removes his receiver from his telephone switch-hook preparatory to making a call, a circuit is thereby

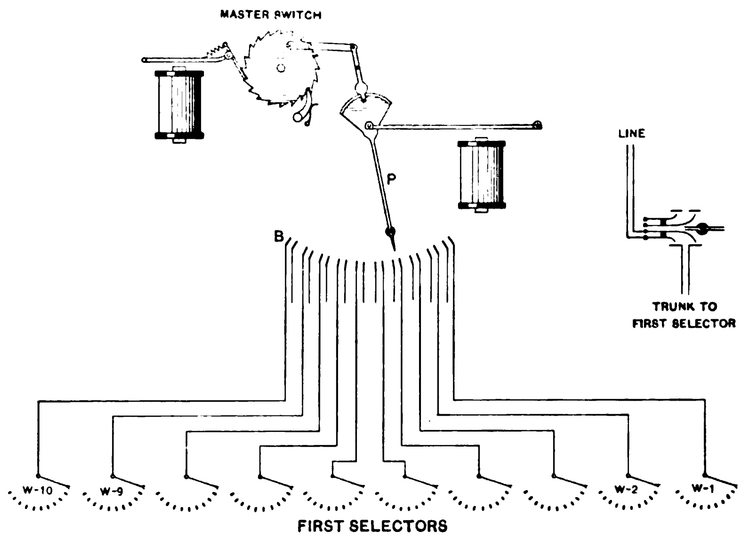

FIG. 15

closed which causes the plunger arm of his line switch to be instantly pulled down, carrying its plunger out of engagement with the master-shaft and thrusting it into the bank. The effect of this is to connect the subscriber's line to a trunk leading to an idle first-selector switch, as shown diagrammatically in the right-hand portion of Fig. 15.

The instant that one line switch thrusts its plunger into the bank, thus occupying the trunk over whose multiple all idle plungers have been poised, the master-switch operates and swings the remaining idle plungers forward over the next multiple of bank contacts. If this trunk should be busy, the movement pro-

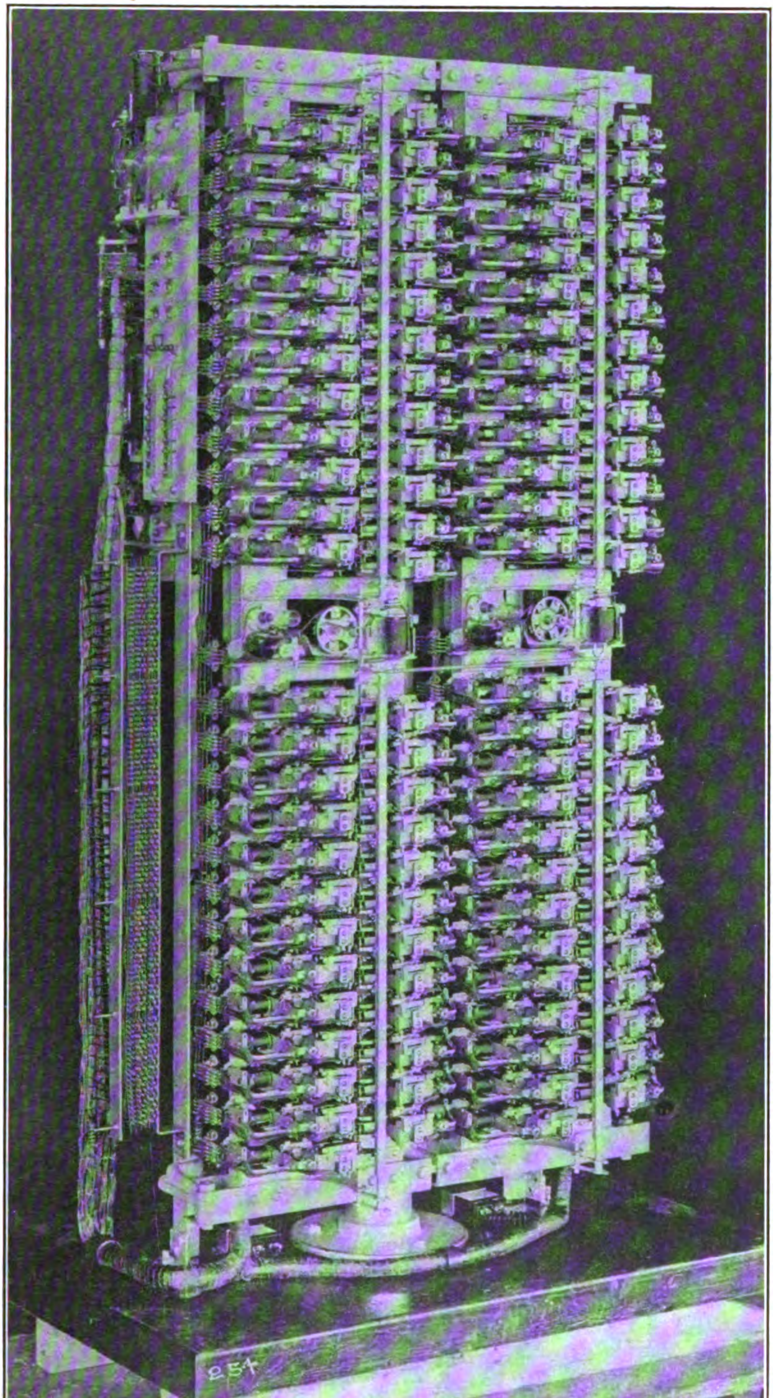

FIG. 16

ceeds until an idle trunk is found. It is to be noted that a line switch always uses a pre-selected idle trunk instead of making a selection after a subscriber starts to call as the Strowger selector switches do. This is quite an important feature and saves considerable time in establishing a connection.

Ordinarily the banks of 100 line switches are multipled together and connected to 10 first-selector trunks, but for four-party line service or extra heavy traffic, the number in one multiple is often reduced to fifty. Fig. 16 shows a front view of a complete line-switch unit with 100 line switches and two master-switches mounted. Only one master-switch is used at a time, the other being held in reserve. Fig. 17 is a rear view of the same unit showing how the 10 connector switches used for handling calls incoming to any 100 lines are mounted on the same upright as the line switches handling their outgoing calls.

While the primary object of the line switches was to reduce the cost of the switchboard by eliminating 90 per cent of the comparatively expensive first-selector switches, they have also simplified the central office equipment and have reduced the space required for it. Further, they have resulted in several new and somewhat radical departures in the art of building automatic telephone systems. The most important of these is the line-switch district station which enables very considerable savings to be made in underground and aerial cable.

A district station is installed by placing one or more line-switch units complete with connector switches in a small building at the telephonic center of a district, generally a mile or more distant from the nearest central office. The lines of all telephones in the district are brought to the district station and are there connected to the line switches. The first selectors to which these line switches are trunked remain at the nearest large central office, consequently when a district station subscriber removes his receiver from his switch-hook preparatory to making a call, his line switch instantly puts him into connection by means of a trunk with a first-selector switch at central office. The connector switches for handling the calls to the district station telephones are mounted in their usual places on the back of the line-switch units, and are connected by trunks to the banks of second selectors, also located at the nearest central office. Thus all calls from and to the district are handled over trunks instead of over subscribers' lines.

Since, as already stated, there are usually but 10 first

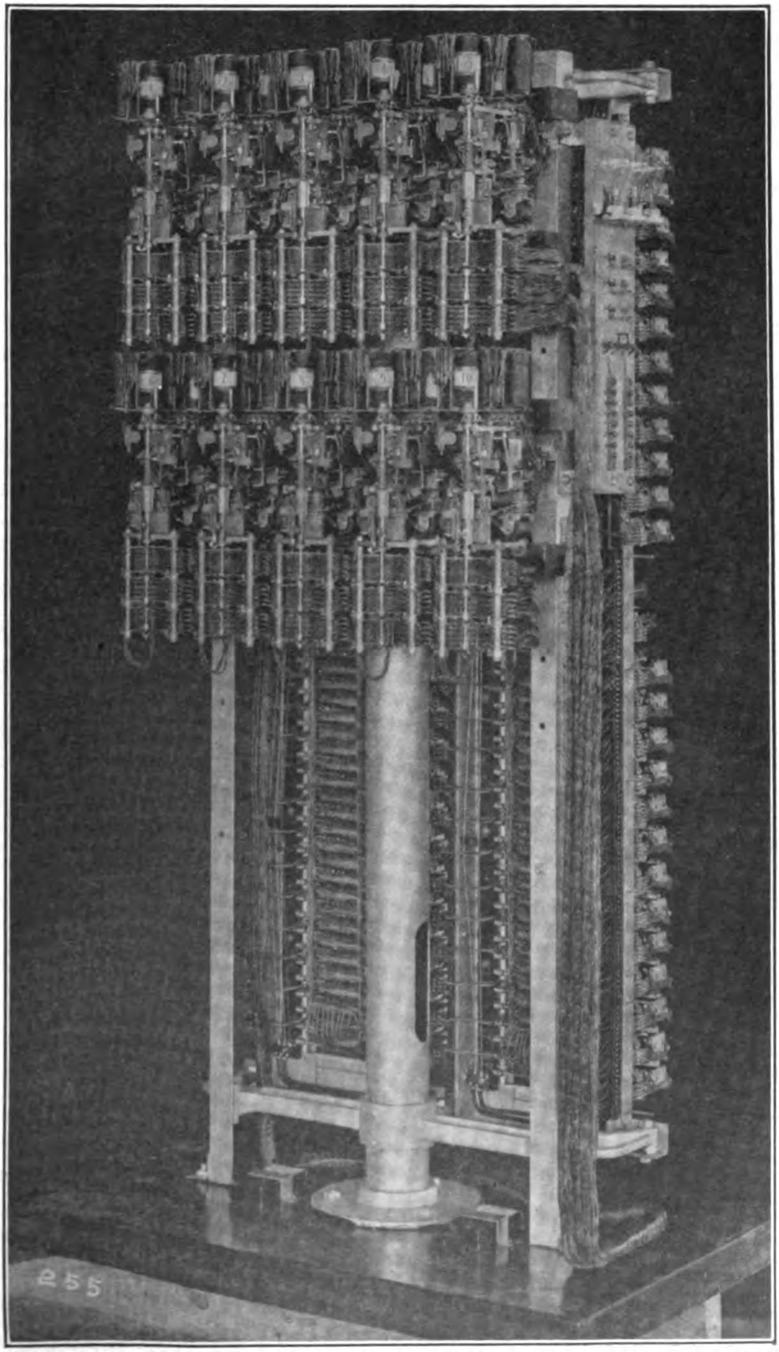

FIG. 17

selectors and 10 connectors for each 100 lines, and since but three pairs are needed for testing and supervisory circuits to the district station, a total of 23 trunk pairs is sufficient between the station and the central office. This leaves a net saving of 77 pairs of wires per 100 lines. In district-station practice stations of less than 500 subscribers are generally unattended and supervised entirely from the central office to which they connect. This is so thoroughly worked out that the wire-chief can test every line entering each district station without leaving his desk at central. Stations of 500 lines or more are generally put into a combination residence and office building so that one attendant

FIG. 18

living in the building gives the equipment all the attention that it may require at any time.

Fig. 18 shows the exterior of a typical line-switch district station building 15 ft. by 16 ft. with a capacity of 700 lines. Fig. 19 shows the interior of one equipped for 200 lines.

Fig. 20 is a sketch of a notable system in Columbus, Ohio, using one large central office of approximately 10,000 lines, surrounded by 9 district stations, varying in size from 100 to 600 lines. One of these 100-line units in Columbus was installed as an experiment in an underground vault about the size of an ordinary underground manhole, and has now been so operating for about two years.

One can readily imagine that the trunking scheme of this system would be very complicated if each of the small offices shown in the illustration had trunks to each of the other offices. Furthermore the cost of trunks divided into such small groups would be so much greater, that the saving in line wires would be much reduced and in some instances almost wiped out. But using the district stations each having trunks to no office except the central office (placed near the business center of the city)

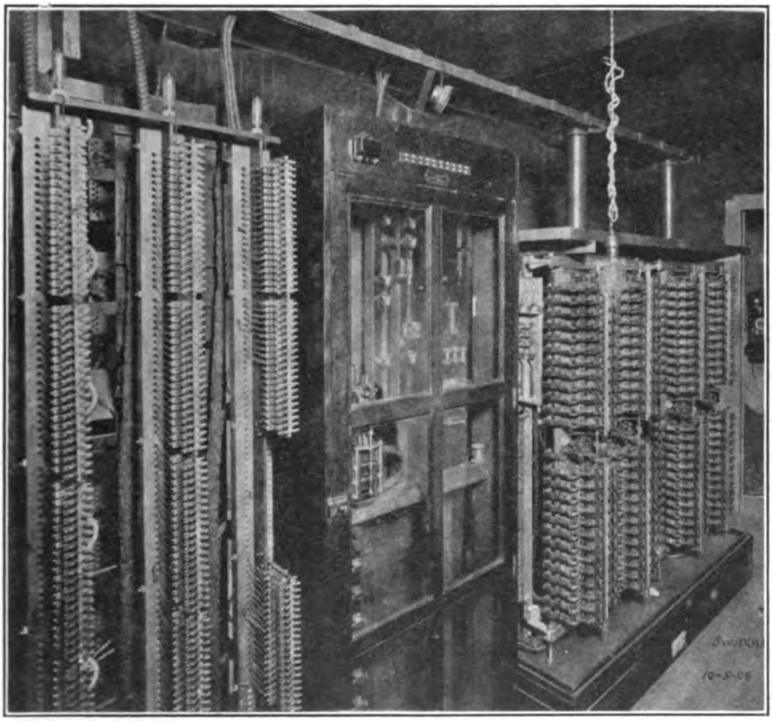

FIG. 19

the trunking plan is a very simple and economical one, and the conditions for centralized supervision of the system are practically ideal.

A new feature called a secondary line-switch has very recently been introduced into the automatic system. The mechanical construction of this switch and of its bank is the same as that of the regular or primary line-switch, and it is mounted and controlled by a master-switch in the same manner. The purpose

of the switch is still further to reduce the required number of first-selector switches, and their trunks. As explained, it has been the general practice to install a number of first selectors equal to 10 per cent of the number of subscribers' lines. Observations made in numerous plants at the busiest hour of the day, however, show that at the peak of the load not more than

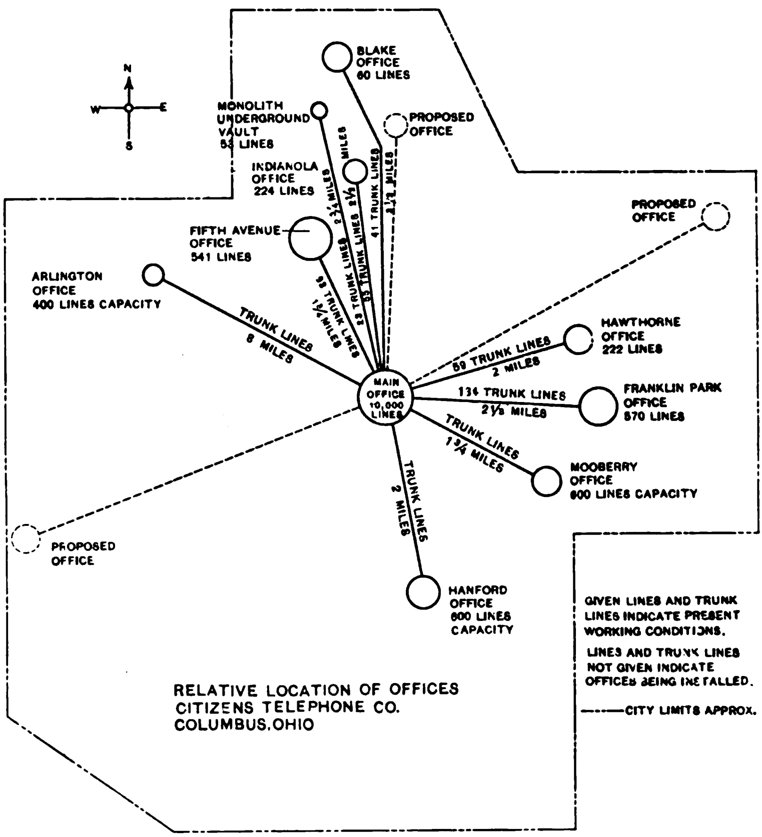

FIG. 20

from 1.5 to 5 per cent of the subscribers are using first selectors. The percentage is smaller in the larger plants and greater in the smaller plants, being about 5 per cent for a plant of 1000 lines and not over 2 per cent for a plant of 10,000 lines. This reduction in the percentage of trunks required as the number of subscribers' lines increases, follows a law well known among telephone engineers. The secondary line-switch takes advantage

of this principle by making it practicable to give 2000 or 2500 subscribers' lines access to one group of 100 first selectors. The secondary switches are inserted between the line-switches and the first selectors in such a way that the primary line-switches pre-select idle secondaries and the secondaries pre-select idle first selectors. Therefore, when a subscriber lifts his receiver from the switch-hook preparatory to making a call, his line-switch and the secondary to which it connects him operate almost in unison. This re-selection of trunks, combined with a rather complex system of cross-multipling, accomplishes the desired

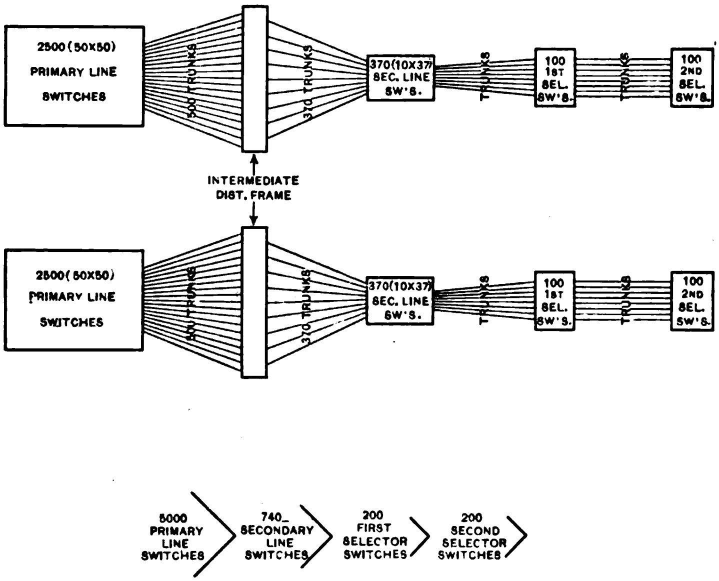

FIG. 21

result of giving a large number of subscribers access to one group of trunks, and thereby reduces the number of trunks and first selectors. It is obvious that if the first selectors are at a considerable distance from the line-switches, for example, in a central office while the primary and secondary line-switches are in a district station, that these secondary switches will save materially in the cost of trunks to the first selectors.

Fig. 21 shows the use of secondary line-switches in the general trunking equipment scheme for one of the automatic offices now being installed in Havana, Cuba. This office is equipped for 5000 lines. The line-switches are divided into two large

groups each of 2500 lines, and each consisting of 50 small groups or multiples of 50 lines each. The trunks from a 2500-line group pass through an intermediate distributing frame to 370 secondary line-switches, arranged in 10 sets of 37 each. Each of the 10 sets has trunks to 10 first-selector switches. Thus, all calls from 2500 lines will be handled by 100 first selectors.

An automatic system equipped for 15,000 lines divided among four offices, was installed in San Francisco last year. Secondary line-switches are there used between the line-switches and the first selectors and are also used to reduce the trunks between offices. In former practice each inter-office trunk terminated in first-selector banks at the calling office, and in a second-selector switch at the called office, but in San Francisco each trunk between offices terminates in secondary line-switch banks at the

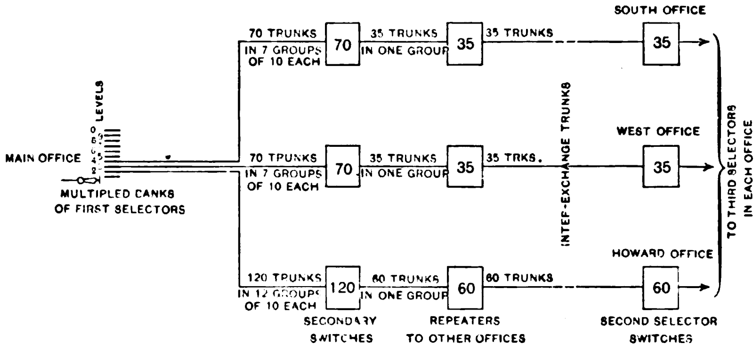

FIG. 22

calling office. Then, short local trunks connect the secondary line-switches to the first-selector banks. Fig. 22, illustrates the trunks outgoing from Main office to Howard, West, and South offices, indicating that the secondary line-switches reduce the trunks to Howard office from 120 to 60, the trunks to West office from 70 to 35, and the trunks to South office from 70 to 35, by combining the trunks coming from the first-selector banks in groups of 10 each, into one group to each office.

Inter-office trunks in automatic systems are equipped with another piece of apparatus which is also indicated in this sketch and which is called a repeater. This is simply a set of relays, and derives its name from the fact that it repeats the calling-device impulses from the subscriber's line to the trunk. It serves another important purpose, for through its relay coils,

talking current is supplied to the transmitter of the calling subscriber.

Talking current is always supplied to the called subscriber's telephone through the connector switch used in calling him. Such an inter-office talking circuit is shown diagrammatically in Fig. 23. Each subscriber always receives talking current from the office in which his line terminates. This is in conformity with the best practice which requires that the subscriber's "loops" shall be as short as possible, and as nearly alike in resistance as conditions will allow. This makes it practicable to supply all transmitters with sufficient current through small and economical line wires, and to supply them all with comparatively the same amount of current.

The length of this paper precludes a discussion of the mechanical details and circuits of the machines and their accessories, even if it were thought that a considerable number of the members of the Institute would be interested in such a discussion.

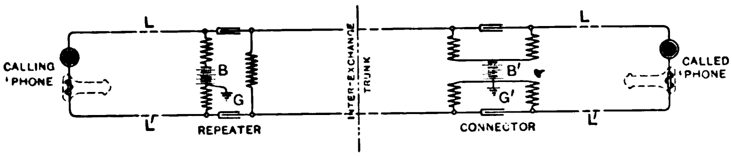

FIG. 23

There are just two measures of permanent success for any telephone apparatus. One is its popularity with its users and the other is the profits it affords the owners. Numerous investigations, some of them made on a very large scale have, to the best of the writer's knowledge, always resulted in the verdict that automatic telephone service is preferred to manual service by the large majority of telephone users, and while the first cost of the equipment is greater than that of manual equipment, the elimination of operators' wages, the saving in building space, and the savings in cable and conduit (discussed at length in the writer's Atlantic City convention paper) have generally made automatic equipment a more profitable investment than manual equipment.

While a considerable number of small private automatic plants are in use, public automatic systems are generally confined to cities and the larger towns. For where a manual switchboard

is so small that during a considerable portion of the day one operator can make all local connections and, in addition, handle all rural and long-distance calls, it is very difficult and generally impossible for an automatic switchboard to compete with it. The larger the system the more economical automatic apparatus becomes. It is a matter of common engineering knowledge that automatic machinery is not warranted in any class of work until the output desired becomes sufficiently large.

Stating the Case Differently

When automatic machinery is substituted for manual labor it is generally for three purposes.

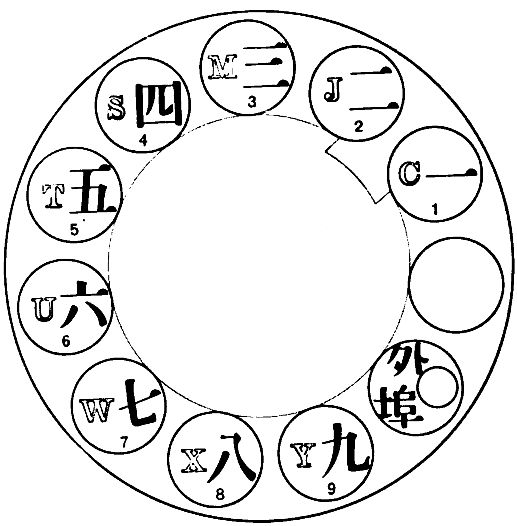

Fig. 24

1. To increase and quicken production.
2. To reduce the cost of the product.
3. To secure uniformity both in the quality or form of the product and in the time required to make it.

These results have been generally attained by automatic machine telephone switchboards. Almost every one likes to feel that the making and breaking of each connection is entirely in his own control. The quickness with which connections are obtained appeals to the subscribers, and in relation to this it is to be noted that while connections are generally obtained more quickly than in manual service, the difference in time seems

much greater to the subscriber than it really is, for two reasons: first, he is occupied in turning his dial while the connection is being put up, and the time, therefore, passes more quickly than it would were he waiting for an operator. Secondly, subscribers generally answer calls received through automatic telephones more quickly than those received through manual telephones. This can readily be explained by an example: For instance, a grocer will answer his automatic telephone more promptly, because he knows that the customer calling him will hold him directly responsible for any delay; otherwise the switchboard operator would probably get the blame.

The instantaneous disconnection is another good feature which is appreciated by any one who has occasion to call several numbers in rapid succession.

Bankers, doctors, and others, who have private matters to discuss over the telephone wire appreciate the comparative secrecy of the system.

The uniformity of the service at all hours of the day or night, holidays and Sundays included, is attractive to many.

A foreigner or a person who does not speak plainly often has considerable difficulty in getting an operator to understand correctly the number of the subscriber with whom he wishes to be connected. This is even a common cause of complaint among telephone users who move from the southern part of our own country to the northern part. Fig. 24 shows a calling-device number disc such as used in the Chinese quarter of San Francisco. This disc is equipped with Chinese characters, and up to this time the section of the automatic switchboard which serves "Chinatown" is one of the busiest in the exchange.

A Word with Reference to the Future

Although inventors have been giving attention to automatic switchboards as long as to manual switchboards, and although automatic equipment has passed through as many stages of development, and in many instances through stages of development similar to those through which the manual apparatus has passed, yet the former has not by any means reached the dead level of "no more beyond" that the latter has. From one view point this is discouraging, but on the whole it is inspiring, for while those who are most familiar with automatic equipment are most painfully aware that it has not yet been brought to its highest possible state of development, they

are, at the same time, its most enthusiastic admirers, and they hope, by further development, simplification, and reductions in first cost, that many families who cannot now afford telephone service of any kind will have it offered to them at a price which they can pay and that the telephone will thus eventually become a universal household necessity. They also hope that the automatic operation of many long-distance lines will greatly increase their capacity and consequent efficiency. This has been tried on a small scale between Columbus and Dayton, Ohio, with very encouraging results. Inasmuch as both of these cities are equipped with automatic switchboards for local service, it was only necessary to have a toll line terminate in the automatic switchboard in one city and in a calling device before a long-distance operator in the other city to make a trial. It was found that connections could be put up much quicker than in the ordinary way. This plan is used very satisfactorily by several automatic companies for handling their own short local toll lines, by giving the operator at each suburban town a calling-device, and allowing her to call all parties in the city automatically without any supervision at the city end of the line. While the opportunity for an operator cheating the company by not reporting all fees earned and collected is greater than with double checking, this has not been found to be a serious drawback. In fact, it is possible to bridge an ordinary stock ticker across the line in such a way that it records every call the operator makes and the length of every conversation. It has been found, however, that the knowledge that this could be done, and might be secretly done at any time, has been sufficient to prevent any tendency toward dishonesty. Careful tests and comparisons made by one company using a considerable number of these short automatic toll lines showed that sufficiently busy lines handled three times the number of conversations that was possible with the former arrangement.

NOTE

The following papers are to be read at a joint meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers at the Auditorium of the Boston City Club, 9 Beacon Street, **Boston, Mass., Wednesday, February 16, 1910, at 8 p.m.** This meeting is to be held under the auspices of the **Industrial Power Committee** of the Institute. All members of the Institute are invited to be present and participate in the discussion.

Written contributions will be read at the meeting, either in full, in abstract, or as a part of a general statement giving a summary of the views of the contributors.

The object of issuing the papers in advance of the meeting is to increase the interest and authority of the discussion by affording those desiring to participate a longer time for the study of the papers and the preparation of their views. The subject is particularly live, and pertinent discussions are solicited.

Those desiring to contribute to the discussion of these papers, either orally or by letter, should notify **Dugald C. Jackson Chairman of the Boston Section, 84 State St., Boston, Mass.,** not later than Feb. 14, 1910. Written contributions should be in his hands by that date.

A paper to be presented at a joint meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, Boston, Mass., February 16, 1910.

(*Subject to final revision for the Transactions.*)

THE APPLICABILITY OF ELECTRICAL POWER TO INDUSTRIAL ESTABLISHMENTS

BY DUGALD C. JACKSON

In two papers on electrical power for factory purposes which were published 14 years ago in the Journal of the Western Society of Engineers and the Transactions of the American Society of Mechanical Engineers, respectively, I set forth the status of the then rather new practice of utilizing electrical power distribution in manufacturing establishments. In this paper, I propose to describe the present status of electrical power in factories, and will point out certain remarkable changes which have arisen on account of improvements in methods of using electrical power and improvements in prime movers adapted to driving electrical generators.

A great change has arisen in the attitude of mill and works' owners toward electrical power, following the demonstration of certain of its qualities—especially those qualities which have contributed convenience in the arrangement of machinery so as to save floor space and to accelerate output, quicker speeds for machines or closer adaptation of speeds to the needs of high-grade manufacture, cleanliness in work rooms, and safety to employees. First creeping into use in manufacturing establishments as an auxiliary readily added in connection with electric crane service or to operate isolated or special features, electric power has now come to an established place, and it is needless to discuss its advantages in factory service compared with mechanically distributed power.

Whenever water power is available, but not contiguous to the most convenient factory site, electrical power is essential to the highest success of a manufacturing project, because by it the

power of the water may be conveniently and reliably delivered for use in the most effective manner at the most desirable site. The power of several waterfalls may in the same manner be converged upon a single factory site, which may either be contiguous to or distant from the stream providing the power These advantages are effectively utilized by many successful manufacturing establishments; and they lie at the root of the success of the great power transmission plants constructed for the purpose of providing a general power supply. Even when water power in large quantities is available directly alongside suitable factory sites, the electrical distribution of the power may play a part of sufficient importance to enable it to supplant mechanical methods on account of its flexibility, which leaves the mill architect free to arrange his factory buildings to suit the requirements of manufacturing product, substantially untrammeled by those difficulties that always surround the transmission and distribution of power by mechanical means.

Also, in these days of perfected electrical power distribution for factory purposes, a multiple of boiler and engine rooms (or water-wheel rooms) located at various points on the premises has become not only unnecessary, but is recognized in most instances as wasteful. A single power house where electrical power is generated for distribution to all parts of the establishment provides a more convenient and economical arrangement. The recognition of this truth is to be observed in the power arrangements of manufacturing establishments in industrial communities from the Atlantic Coast to the Rocky Mountains, wherein each more important of the recent establishments has its individual electric power house built with a comprehensive eye to economy, conveniently located on the property, and therein are located the only prime movers of the establishment. Steam-driven power houses of this character may be located on the most favorable part of the property for the receipt of coal and supplies and the disposal of ashes, and with a proper eye to prevent inconvenience in the manufacturing processes from the smoke and dirt that ordinarily accompany the processes of generating steam power.

In a similar manner the old and ineffective plan of dividing water-wheels amongst several power houses along a canal, where large amounts of power are to be used in an establishment, and adapting the factory buildings to the locations of these power houses—a plan characteristic of many of the older textile

mills of New England—may now be replaced by the much more effective arrangement with a single water-driven electric power-house located at the most advantageous hydraulic position on the canal. The factory buildings may then be grouped and arranged as best suits the requirements of economical manufacturing, without limitations caused by inflexible mechanical means for distributing the power. By the electrical distribution, the power may be put wherever it is needed with convenience, economy, cleanliness and safety, and to any amount needed.

Advantages are thus derived from both the manufacturing aspect and the aspect of power generation *per se* from utilizing electrical power distribution in connection with important industrial plants. Steel works, with their valuable by-product of gas-power from blast-furnace gases, make striking instances of the use of comprehensive, unitary, works' power-generating plants under conditions which formerly would have required at least several power plants scattered about the works. These are striking instances illustrating the present tendency, but many similar illustrations are to be found amongst the factories in nearly every important branch of industry.

The centering of power generation into a single generating plant for any large establishment is accompanied by economies in power generation that are of themselves appreciable, besides contributing to reliability. The question that I wish particularly to bring to your attention is: how far should such concentration proceed?

Without the electrical distribution of the power, such concentration could not be adequately carried out at all. Moreover, whatever limitations still exist toward improving the economy by completely concentrating the power generation in any industrial establishment, exist with respect to the prime movers and not with respect to the electrical distribution of the power. Where hydraulic prime movers are to be considered, the concentration may ordinarily be made as complete as the conditions of the water supply will permit, since the charges on account of first cost of installation and the labor cost of operating practically dominate the cost of the power developed, and these may ordinarily be expected to decrease per unit of output as the capacity of the plant is increased, under conditions of equal or improved load-factor.

An equivalent condition has not heretofore existed where steam prime movers have been used. Since neither labor cost

nor steam economy are much improved by increasing a steam-electric generating plant over a size of a few thousand kilowatts capacity when reciprocating engines are used, the need of extreme concentration of individual plants has not heretofore been acutely felt. But the advent of large steam turbines has altered the conditions. Plants equipped with these machines installed in association with boilers provided with adequate labor-saving appliances may be operated with labor costs that vie with the labor costs pertaining to hydraulic generating plants equipped with machines of equal size; and the steam economies derived from the newer steam turbines are remarkably satisfactory. As this paper is limited by the program-makers to an introduction to the more specific papers on electrical power for industrial establishments, I cannot here enter upon a discussion of steam-turbine economies and their influence on the generation of electrical power for manufacturing establishments; but my purpose is fulfilled by emphasizing the fact that the operating economies of large steam-turbine plants, either in respect to the use of labor or the use of fuel, do not seem to be exhausted within the limits of capacity yet attained in even the largest generating plants now in commission. Moreover, the first cost per kilowatt of capacity of plant, including land, buildings, and machinery, falls off in an important degree for the larger steam-turbine plants, until such a plant may nearly rival a hydroelectric plant in the gross cost per kilowatt-hour of energy delivered at the switchboard, through the fact that the fuel cost pertaining to the steam-turbine plant has an offset in the charges caused by larger first cost per kilowatt of capacity of hydraulic plant. Mr. Stott's curves* illustrate this point clearly.

These considerations indicate that concentration of steam-electric generating plants will afford considerable economies when the concentration is carried much further than heretofore, provided large steam turbines are utilized as prime movers. The ultimate economy cannot be reached in a single factory plant, even when it comprises several thousand horse power; and logical development leads beyond the present practice of concentrating the power units of each manufacturing establishment into an individual power plant. Economy and reliability in power service are both to be obtained by further concentrating such individual power plants located in a compact

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* PROCEEDINGS Amer. Inst. of Elect. Eng., Apr. 1909, p. 283.

industrial center into one or more great central stations each of which provides power for a number of establishments.

The usual round estimate of the cost of power in machine-shops and the like is $60 per horse power per year—taking the average power during working hours, perhaps 9 hours a day on the average. The cost is probably fully that large, as the power in machine-shops seldom exceeds a couple of hundred horse power and often does not exceed one hundred horse power. The load-factor is also rather low. Under more favorable conditions, large reductions may be made compared with this figure. In the case of a mill using an average of substantially 2000 h.p., for 24 hours per day, 313 days in the year, the cost per indicated horse power per hour may be reduced to the following figures in case a good compound condensing Corliss engine is used and the boiler firing is intelligently supervised. The cost of coal is put at $4 per ton on the cars at the purchaser's siding, and it is supposed to cost 25 cents per ton of fuel to put the coal in the power-house bunkers and to dispose of the ashes. As my experience with power plants located in New England is limited, I refer to conditions in parts of the country with which I am more familiar; but the data apparently apply equally well to New England conditions.

Under the conditions referred to, the costs are substantially as follows, per indicated horse power per hour in a well-run plant:

	Cents
Fuel, oil, waste and repairs	.42
Labor	.08
Insurance (boiler, liability and fire), interest (at 8%), depreciation and taxes on power plant including building and land	.15
	0.65

This is based on horse power measured by steam-engine indicators on the engine cylinders, and (on account of power losses and other expenses) the cost may be increased 50 per cent or more for the power mechanically delivered to the centres of use in the mill; in which case the cost would correspond to a central station charge of as much as 1¼ cents per kilowatt-hour for electrical power delivered to motors of large size carefully located in the mill. When running the same plant ten hours per day instead of twenty-four, the cost would come to substantially one cent per indicated horse power per hour, and when

mechanically delivered to the centres of use, the cost of the power may reach a rate corresponding to a central-station charge of as much as two cents per kilowatt-hour. In small plants and plants with a less favorable load-factor, the cost is ordinarily much higher; the illustration which I have taken relates to power generated under conditions particularly favoring a low cost per horse-power-hour for an individual industrial plant.

The mill using 10 per cent more power at the maximum than is required on the average, and operating 313 days of 24 hours each in the year, gives substantially 78 per cent annual load-factor based on an installation of a rated capacity equal to the maximum load. If the 10 per cent by which the maximum load exceeds the average is expected to be carried by the margin in the capacity of the machinery over regular rating, as it properly may be in cases where the extra load only occurs for brief periods when the mill is cold after having been shut down, or for some similar reason, the annual load-factor of the machinery is substantially 86 per cent. With a load-factor like this, a large turbine station can generate electrical power at a remarkably economical rate. It is three times the load-factor ordinarily pertaining to electric lighting stations.

Putting this mill on a 9-hour regime for 313 days in the year, would bring its annual load-factor down to little over 30 per cent and would increase the cost of the kilowatt-hour. The load-factors of the run of manufacturing establishments rule less than this, as the power consumption is generally subject to more variations than in the mill that I have chosen for illustration.

Even with the conditions named in my illustration, a large properly designed and built turbine station delivering power to a considerable number of factories ought to be able to improve a little on the power costs and add something to reliability. The requirements for heating mills and the use of steam in various manufacturing processes often make it impossible to remove the means for generating steam from the factory site, but the generation of steam for power purposes is commonly accomplished separately on account of the different pressures needed for the two purposes, and the separation is therefore a matter to be dealt with as of manufacturing convenience rather than as controlled by economy of steam generation.

It therefore seems that we have before us a certain definite character of development in the power generation for our industrial cities. Electrical distribution of power has made its

way in factories of all kinds of product, on account of its adaptability to diverse requirements; that is, on account of what we commonly refer to as its flexibility. It has proved particularly advantageous on account of its ready adaptation to delivering power wherever and in whatever position the best interests of getting out product demands; on account of its joint properties of steadiness of speed and controllability of speed, which have contributed to increasing both the quantity and quality of product: on account of cleanliness, reliability and safety, which have also strongly commended its use. Its use has also ordinarily proved economical from the standpoint of cost of horse power applied to the machine shafts. The advantages of flexibility and speed-control are being constantly widened by wiser designing of motors and their appurtenances, as experience extends. Economy and reliability are being additionally provided in the improved designs and more substantial construction of new power houses. But one of the important possibilities for densely crowded industrial cities is still almost untouched. For instance, in the city of Philadelphia many tens of thousands of horse power are used for manufacturing in establishments crowded together in city blocks, and the power is developed in separate large and small power plants located, as physical conditions warrant, in each establishment and with a minimum consideration given to economy. Several (perhaps three) large steam-turbine electric power houses, located on tide water aside from the densely occupied areas and constructed with a careful eye to minimizing the cost of the kilowatt-hour, could profitably supply this power at figures corresponding with its existing cost, and at the same time release for productive purposes large parts of the very valuable space now occupied by individual factory power plants. This would also relieve the thickly occupied parts of the city from the smoke and dirt that have become seriously objectionable, and would also remove the inconveniences now relating to providing the fuel supply and discarding the refuse. Some of the advantages of concentrating the power supply for large cities were urged in the address of President Ferguson at the Frontenac Convention of the American Institute of Electrical Engineers and by President Stillwell at a meeting in New York City.* It is unnecessary for me to discuss them further here.

* PROCEEDINGS Amer. Inst. of Elect. Eng., August, 1909, p. 1055 and May, 1909, p. 317.

Much is now being said of "city planning." Some of the proposals seem to be founded on pure altruism, but others are obviously founded on economy. The city planners of crowded industrial cities have an opportunity which joins economy with altruism in studying the applicability of electrical power from centralized generating stations to large and small industrial establishments. There is here an opportunity for the betterment of crowded larger industrial cities that ought not to be overlooked. It has its possibilities also in the smaller industrial cities. The possibilities are larger and more real than appear at first view, but the limits of the program will not permit me to enlarge upon them by illustrations and argument. I lay this before you as one of the most important and desirable ways in which the proved applicability of electrical power to industrial establishments may be utilized for the betterment of crowded factory areas.

A paper to be presented at a joint meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, Boston, Mass., February 16, 1910.

(*Subject to final revision for the Transactions*)

CENTRAL STATIONS VERSUS ISOLATED PLANTS FOR TEXTILE MILLS

BY CHARLES T. MAIN

Textile mills are in the business of manufacturing tops, yarns, cloth, carpets, or some other product for the market. The production of power required is an incident or detail, and usually the cost of power does not exceed 5 per cent of the value of the product. In selecting a location for a new mill it is important carefully to consider the source and cost of power—and in estimating the value of a mill already existing—but the power is only one item for consideration and it should not be allowed to play too important a part in the decision.

The chief items of cost entering into the product of a textile mill are usually materials and labor. It is therefore more important to locate in some place where skilled operatives in the particular kind of business to be carried on can be obtained at reasonable wages, or where there can be obtained help who can be trained, and where the cost of transportation of raw materials and finished products is relatively a small amount, than it is to seek a location where cheap power can be obtained but where the other items are lacking. A saving of 10 per cent in the cost of power would represent a saving of not over one-half of one per cent in the cost of the product. The relative importance of locating a plant with reference to cheap power increases as the ratio of the cost of power to the value of the product increases.

Most of the earlier mills were located on rivers, and it was due to such water powers as were developed on the Merrimac, Connecticut, Blackstone and other rivers that the manufacturing cities were begun along their banks.

Most of these powers within reasonable reach in New England

have been outgrown, and now there is found in some of the manufacturing centres a great preponderance of steam power over water power. New centres of manufacturing on tidewater have grown up which have little or no water power, but which can obtain cheap coal and low rates for transportation, and some of the most prosperous mills are driven by steam power.

In recent years the transmission of power by electricity has made it possible to locate the mills more advantageously for construction, light, railroad facilities, etc., and has made valuable water powers which on account of their location were hitherto valueless, and has enabled the construction of central steam plants to be located at the mouth of the mines or at tidewater where cheap fuel can be obtained.

Items in Cost of Power

It can be said generally that the cost of producing power may be divided into two parts:

1. *Independent charges*, or the part which is independent of the output, embracing fixed charges on the plant—as interest, depreciation, insurance, and taxes, and, to a certain extent, repairs.

2. *Proportional charges*, or the part which is proportional to the output, including such charges as coal, labor, supplies, etc.

In general, steam plants may be said to have low independent charges, and high proportional or operating costs.

Water-power plants are usually the reverse, with high fixed charge accounts and low operating costs.

Another item which should be mentioned as affecting the cost of power is what Dr. Steinmetz calls the "reliability-factor," which takes into consideration the spare machinery needed to insure continuous service. The charges on this spare equipment are apt to have quite a bearing on the cost of power in a central station supplying power for sale, where reliability must be one of the chief considerations, and more spare or duplicate plant is usually maintained than in a private plant.

Factors Affecting the Cost of Power

The chief conditions which affect the cost of steam power, are as follows:

1. Cost of fuel delivered to the furnaces.

2. Amount of power produced.

3. The load-factor in its relation to fixed charges, whether the power is continuous and uniform, or intermittent and variable.

4. The net cost of power is reduced considerably in some concerns where the waste heat of the power plant can be used in the manufacturing processes in the form of low-pressure steam or warm water.

The chief conditions which affect the cost of water power are as follows:

1. Fixed charges on the development.
2. Amount of power produced in its relation to fixed charges.
3. The load-factor in its relation to efficiency of wheels, pondage, and reservoir capacity.
4. The cost of supplementary power necessary to make up for the fluctuations of the water power, if required.

Variation in Cost of Steam Power

Steam power costs the most per unit of power when produced in small amounts. The cost is increased for fluctuating loads, and when used for purposes where the load-factor is small. By load-factor in this instance is meant the average output in per cent of the full capacity of the plant.

Steam power costs the least per unit of power for comparatively steady continuous loads, as for paper mills and other similar industries; and the cost may be still further reduced where there is use for exhaust steam or other by-products from the plant. Such conditions as the last are found in color textile mills. Power costs the most in plants having a low load-factor with a variable load, and where there is no use for the by-products of the plant, as in a lighting or street railway plant.

Textile mills usually run about 10 hours a day, and have a comparatively low load-factor, but while the load is on, it is usually fairly steady. Public service plants usually have a load-factor somewhat lower than that in textile mills but the load is variable, which is not so favorable to economical operation as the textile load would be.

So far as we know, the net cost of steam power is the least, and the net value of water power also the least, for color textile mills of any of the important industries. This is due to the usually steady load and to the fact that the waste products from the steam plant are valuable for manufacturing purposes to those industries.

The net cost of steam power for textile mills gradually increases from the costs to the mill which can use all of the waste products which will have the lowest cost, to the case of mills

making white goods where only exhaust steam for warming the building and drying the yarn in the slashers can be used. In order to give a general idea of the usual costs of power under ordinary conditions in this section of the country, an analysis of the cost of power for a station of 2,000 kw, capacity is given below. This station is similar to some which have been constructed within the last few years.

As electric drive is becoming so common in textile mills, we will assume for the basis of these costs that the stations considered below will be electric, and of 2,000 kw. capacity, composed of two 1000-kw. units. Usually there is no spare apparatus in these plants. This may be considered as fair average practice at present for textile plants, but would not be tolerated for public service plants where reliability is necessary.

In making up the cost of power, all charges have been considered except the interest charges and taxes on the cost of land. These are usually not large items in textile mills, and are variable. The cost of land for the station has also been omitted from the cost per kilowatt of the station.

In making up these costs, interest has been taken at five per cent depreciation and repairs on the apparatus for 10-hour power at 5 per cent and on the building at 2.5 per cent insurance and taxes at 1 per cent, making a total of 11 per cent on the apparatus, and 8.5 per cent on the building. For 24-hour power, the depreciation and repairs on apparatus is increased 2 per cent thus making the total charge 13 per cent instead of 11 per cent. A small amount is added in both cases for incidentals.

These rates of depreciation would not be proper for a station where the manufacture of current was the main product as for a public service plant, for newer and more efficient types of apparatus would make it necessary to discard apparatus which was mechanically good. This course would not be so necessary in a manufacturing plant where the saving of a small percentage of the cost of power is not of such vital importance as are some other considerations.

With a steam engine plant, with direct-connected generators, the cost of the plant per kilowatt of capacity is about $125.00.

The cost of power from this station with coal at about $4.25 a long ton, in the pocket, would be about $33.00 per kilowatt per year of 3000 hours, as a straight power proposition. This is equivalent to about $24.60 per electrical horse power per year, and about $21.50 per indicated horse power per year. This would be a cost of 1.1 cents per kilowatt-hour.

If steam turbines are used instead of steam engines, the cost of the station will be reduced to about $105.00 per kilowatt capacity.

The cost of power produced on steam turbines would also be reduced to about $29.50 per kilowatt-year against $33.00 for the engine plant. A part of this difference is made up from the reduced cost of the station and apparatus, and a part from the better economy of the turbines which we have assumed are using the superheated steam and high vacuum which is common practice.

If steam power were to be generated for 24 hours a day for 6 days in a week, or say 300 days a year, as for a paper mill and a few of the textile mills, the cost of power would be about $57.50 per kilowatt per year for the engine plant and about $53.00 per kilowatt per year for the turbine plant. These costs reduce to 0.80c per kilowatt-hour, and 0.735c per kilowatt-hour, respectively.

The difference in the cost for the two kinds of power is due to the fact that practically the same amount of fixed charges is spread over a much greater number of kilowatt hours. There is also some saving in coal due to the elimination of banking of fires for a large portion of the time.

For industrial plants, under consideration, the load is nearly constant throughout the operating time, which means good operating conditions.

Public Service Plants

In a public service plant, even with the same load-factor as for the 10-hour textile mill which would be high for most of these plants, the operating conditions would not be so favorable as in a textile mill as about the same amount of banking would have to be done, and the prime movers would have to operate at variable loads. This latter undesirable feature would not be so serious in a large station as in a smaller one, so far as the efficiency is concerned, as the variation could be more nearly cared for by varying the number of units and thus operating all of them at advantageous points.

The cost of power for this type of plant is more, other things being equal, than for a plant of the same size for a textile mill having the same load-factor. This is due to the effect of variable load towards a reduction in efficiency, and because of the greater cost of plant and consequent greater fixed charges per unit of output.

It should be borne in mind, however, that these public service plants are usually of very large size, and that their output delivered has to compete in price with the cost of power from very small stations. This would give the advantage all to the central station as far as the actual cost of making power is concerned. To the cost of making the power, the central station must add the cost of transmitting, distributing, and selling it.

These additional costs probably form a very large part of the total cost to the purchase of the power. The distribution of power in a city is expensive, meters must be read, accounts kept, bills collected, etc. So that while a central station may deliver a kilowatt-hour at the switchboard for less than one cent, it can hardly afford to sell it for that.

Some years ago, the manager of some large public service properties, testified that the cost of power to a plant of this type could not be more than one-quarter of the gross income. A representative of another company made the statement recently that it cost his company more to meter the current for their smallest customers than it did to generate it.

Effect of Use of Waste Products From Power Plant For Manufacturing Purposes

It has been common practice for many years to use the by-products, such as exhaust steam and warm water, from the steam plant for manufacturing purposes, and for heating buildings, etc. It has been also very common practice to take steam out of the receiver, between the cylinders of a compound engine, for these purposes. In many mills all of the exhaust of simple non-condensing engines is used for manufacturing purposes.

The saving from using the exhaust of a non-condensing engine which would otherwise go to waste, is large, because there is no additional steam required for the engine, unless the back pressure is increased. Any use of the steam is nearly all clear profit, and if all of it is used the only part left to charge to power is the difference in B. t. u. due to the difference in pressure, and the condensation in the engine cylinder and jackets.

There seems to be no good reason why in time the practice of bleeding turbines should not become as common as bleeding engine receivers.

Receiver Steam

Table I shows the amount of coal chargeable to power when certain percentages of the steam entering the high pressure

cylinder are taken out of the receiver. This table takes into consideration the effects on the economy of the engine of not passing all of the steam into the low-pressure cylinder, cylinder condensation, etc. The percentages in the first column are the percentages of the steam passing the high-pressure cylinder which is taken out of the receiver for manufacturing purposes. The second column is the total coal burned and the third is the coal chargeable to power after deducting the coal chargeable to manufacturing.

TABLE I

Per cent of exhaust steam used for heating purposes	Pounds of coal per onehorse power per hour. All coal charged to power	Net pounds of coal per one horse power per hour after deducting for exhaust steam used
0	1.75	1.75
25	2.06	1.50
50	2.38	1.25
75	2.69	1.00
100	3.00	0.75

If the mill did not obtain its power from steam, so that it could use the low pressure steam of the plant for manufacturing, it would have to maintain a boiler plant of sufficient size to produce an amount of steam equivalent to that bled out of the receiver. The amount of B. t. u. or its equivalent in coal chargeable to power is represented by the amount of work done by the engine, and the losses due to the presence of the engine. The cost of generating the rest of the steam is chargeable to the manufacturing processes.

Examples of Manufacturing Plants

A few examples of the reduction in cost of power due to the uses of the by-products from the steam engine plant, and the bleeding of steam from the receiver may be of interest.

In one colored cotton and silk mill, the power to run the mill was about 1800 indicated horse power and for manufacturing purposes about 25 per cent of the steam for this was required in the form of steam from the receiver.

Assuming the cost of power $33.00 per kilowatt year with no bleeding, the cost chargeable to power with 25 per cent bled continuously is $29.75. The saving is $3.23 per kilowatt-year. This was for the use of low-pressure steam alone. Probably another

material saving could be made by using the overflow from the condenser for water for dyeing purposes.

In another mill where much more dyeing was done, requiring a large quantity of hot water, also a large amount of exhaust steam for manufacturing and heating, the cost of power if no steam and waste products had been used, would have been about $34.00 per kilowatt year, but when the proper credits had been allowed for items chargeable to manufacturing purposes, the cost was reduced to about $26.00 per kilowatt-year, or a reduction of about $8.00 per kilowatt-year.

In a plain or white goods mill, where no steam would be required for manufacturing, other than warming the building and slashing, the saving to be effected by using receiver steam for those purposes, would be about $2.00 per kilowatt.

About three-fifths of this, or $1.20 is for heating, and the rest for slashing: so about $1.20 per kilowatt is the amount of the reduction which could be made in heating the buildings of an industry similar to a textile mill.

There are a few plants run by simple non-condensing engines exhausting into the dye-house and if the dye-house is running full there is very little change in the boiler room whether the engine is running or not.

There is one plant run by a simple non-condensing and a cross-compound engine. The exhaust from the simple engine and the condensing water from the compound engine are all used in the dyeing, finishing, and heating. The net cost of coal for power under the two last conditions is small.

In one mill which is run wholly by water power about 12,000 tons of coal are burned annually for dyeing, finishing, and heating the buildings. If a portion, or all of this mill had been run by steam power, the waste products of the steam plant would have furnished a portion of the heat required for manufacturing purposes.

The above are fair examples of the requirements in textile mills.

The Cost of Water Power

The cost of water power depends upon a great variety of factors, but the essential feature is usually the fact as to whether the combined result of all these factors is such as to make the cost of the development per horse power delivered, a reasonably small amount, so that the fixed charges shall not be excessive. In other words, the allowable cost of water power cannot be ma-

terially more than the net cost of producing the same amount of power for the same purpose in some other satisfactory manner, usually by steam.

The cost of maintaining and operating a supplementary steam plant to make up for the shortage of power during low-water, flood periods, etc., must be carefully considered as it affects the actual cost of power delivered from the hydraulic plant.

For the reason that water powers usually have high independent charges they are more valuable for use on loads with high load-factors than with low load-factors, and hence are more valuable for 24-hour power than for 10-hour power.

Many of the modern developments are of very large size and the cost per horse power of the plant is in some cases small. In the determination of the cost of power, the cost per horse power of development should not be allowed to confuse or cause misrepresentation of the actual cost of power delivered. Usually the larger the development installed, the smaller is the cost per horse power of development, but it does not follow in all cases that the cost of delivered power will be smaller per horse power.

There are usually more elements of chance and more unknown factors in a hydraulic development than in a steam plant, and these facts should be taken into consideration and properly cared for. It is the lack of consideration of some of these items that has caused some of the water power developments to get into disrepute.

On the other hand a development properly made and at a reasonable cost is a valuable asset and one which bids fair to increase in value if the price of coal increases in the future as in the past.

Variation in Value of Water Power

The value of a hydroelectric power to various industries will vary in approximately the same ratio as the cost of producing power in some other way, if considered as power, pure and simple, without taking into consideration other important items affecting the business, which are sometimes more vital than the cost of the power itself.

To illustrate the value and cost of power under different conditions, it may be well to mention the two following cases:

A price for hydroelectric power was submitted to a color textile mill, of 1.2c per kilowatt-hour. After due consideration, it was decided that the mill could not afford to accept the offer, the principal reasons being:

1. On account of the use of steam for manufacturing purposes and of the water of condensation for dyeing, the net cost of steam power would be less than the price of hydroelectric power.

2. It was considered better for the textile company to own and control its own plant, if it had the capital to build it, than to purchase current brought over many miles of pole line, and be tied up to some foreign company.

The cost of power per kilowatt at the switchboard from the hydroelectric company for the operating time of the mill was about $36.00 per kilowatt-year; and for the steam plant which the mill was proposing to install this cost was estimated at about $34.00 per kilowatt-year, but if the power had been bought from the hydroelectric company, the mill would have had to install and operate a boiler plant nearly as large as the one required for both power and manufacturing.

It was estimated that the use of the waste products from the steam plant would reduce the net cost of the power at least $8.00 per kilowatt.

In another case an offer from a hydroelectric company was made to furnish power at 1.2c per kilowatt-hour, the same price that was refused by the color textile mill. For a plain cotton mill it was decided proper to accept the offer.

The principal reasons for accepting it were:

1. 1.2c per kilowatt-hour—about $36.00 a kilowatt-year, or $27.00 an electric horse power delivered. This reduced back to one horse power equals about $23.50 per year, which was very near the estimated cost of steam power for the quantity required and at the price of coal for this particular industry.

2. The mill desired to postpone the expenditure necessary for a steam plant if it could be done without serious loss.

Central Station Built by Mills

Steam central-station plants for the distribution of power to textile mills are being built and operated by the mills themselves to considerable extent, because it is acknowledged that a central station of large capacity can be run at less expense than several isolated plants, if considered for power only, without considering the other uses for steam and warm water. It is doubtful, however, if a central plant located at such a distance for the manufacturing processes as to make it necessary to forego the saving which can be made by the use of the waste product of the steam plant can be run as economically as several scattered plants from

which low pressure steam and condenser water can be made of use. In some plants, it becomes a necessity to abandon this advantage owing to the growth of the plant and the necessity of separating the power plant from the mill.

Other advantages may be derived by the concentration of plants which warrant the change.

Nearly all of the recently built concentrated plants are for electrical transmission.

Hydroelectric Station

There are comparatively few hydroelectric plants owned by other corporations which are supplying textile mills in the North with a portion of all the power required by them.

The reasons for this are as follows:

Power costs more and can be sold at a greater price.

The power plants of textile mills are usually of a sufficient size to make them fairly efficient in fuel economy and fairly cheap to run in other respects.

There is usually no large amount of reserve machinery as the service is not severe, and as it is owned and controlled by the company itself, it can take some chances which could not be taken by a power company furnishing power to the mill.

The power plant is one of the items that goes to make up the whole plant, and is so considered. It is usually of very little trouble or care to the manager, and requires no additional salaries outside of the ordinary engineers.

The item of depreciation is not so great as it is in a central power station, for in the mill the cost of power is a small percentage of the value of the product and there is not the necessity of change so frequently in order to get the utmost economy that there is in a power station whose product is power only.

With the mill plant, there are no large charges to be made to transmission costs and losses, to selling and metering the power, to franchises, administration and other charges which are necessary and common to central power stations.

The most favorably situated and least expensive hydroelectric developments can make power and distribute it and sell it to plain textile mills at prices which will be attractive, but it will be quite difficult to sell at prices low enough to compete with the net cost of power to the color textile mills which use their steam power to the greatest advantages from power and manufacturing processes.

Surplus power which can be furnished for less than the whole year must be sold at low prices as the mill must maintain its steam plant for emergency use and run it when necessary, thus adding to the cost of purchased power the fixed charges on the steam plant, and such operating costs as may be met from time to time.

In this section of the country but few of the textile mills have purchased power from any central station either steam or hydroelectric, but in the South, it is not uncommon practice for the mill to purchase hydroelectric power.

Some of the reasons for this are as follows:

Most of the mills in the North are older than those in the South and were built previously to the time of electrical transmission of power. They were, therefore, equipped with their own power plant, either water or steam, or both, and having made the investment there is not the incentive to change, whereas a new plant might save considerable investment in power plant by the purchase of power.

Most of the Southern mills are plain white mills, requiring no large amount of steam for dyeing and finishing, and requiring also less steam for heating the mills.

The mills of the North average larger in size than those in the South, and the larger the plant, the less the cost of power per horse power other things being equal.

As a rule the northern manufacturers are more accustomed to the supervision of their power plants.

Central Steam-Power Plants Owned by Other Interests

There are still fewer textile mills purchasing current from central steam plants, and the reasons for this are the same as stated for the hydroelectric stations.

The central station men claim that the mills do not know how much steam power is costing them. This may be true, in many instances, but not in all. The larger mills know the cost pretty closely.

Advantages to Purchasers of Electric Power

Some of the advantages to the purchaser are as follows:

In a new enterprise, in which the power plant has not already been constructed, there will be required less investment for the power plant with the purchase of current, than if the power is produced by the company itself, and the manufacturing company will have more capital for other uses in its business.

Less space will be required on account of the omission of the power plant and perhaps a better arrangement of buildings can be made on that account.

There will be less care to the managers of the mill if the power is purchased than if it is produced by the mill, but in a textile mill this does not usually seem to be very serious.

The company is enabled to postpone the introduction of a power plant until some later date, and in that way is able to take advantage of any improvements in power plant equipment which might be brought about during the time that current was purchased.

For the above reasons, I should expect that a mill would be willing to pay something more than the bare cost of power if the power were purchased from outside, but the mill should determine what the net cost would be from its own power plant, taking into consideration not only the cost of power, but also the saving due to the use of low pressure steam and warm water for manufacturing purposes.

If power is purchased, there must usually be added the cost of running a boiler plant at the mill for heating and manufacturing purposes in making the comparison with the combined plant at the mill for power, heating and manufacturing purposes.

For the above reasons, the central station will have difficulty in contracting with large textile mills for power except under the most advantageous conditions for the central station and the most disadvantageous conditions for the textile mill.

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(*Subject to final revision for the Transactions.*)

THE SUPPLY OF ELECTRICAL POWER FOR INDUSTRIAL ESTABLISHMENTS FROM CENTRAL STATIONS

BY R. S. HALE

We have heard an account of electric power plants planned for each mill to have its own plant. Now, even if the 2000 h.p. plant is of a size greater than the majority of electric central stations, nevertheless the question at once arises why should we not have a central station larger than most of those of to-day and then let the very large station supply the comparatively small plants with all the possible advantages due to size and combination. This is the question on which I shall dwell.

I am interested in a great central station and this is a very immediate and almost personal question, but the form in which the question comes to a sales manager is always whether some particular owner of a mill or factory can be persuaded to buy electricity, while the American Institute of Electrical Engineers is interested in principles rather than in particular contracts.

The general question of whether a large station can supply power more cheaply than several small ones is, however, one that hardly admits of argument. Still, in order to satisfy myself as to whether 1000 or 2000 h.p. isolated power plants for mills diverge except in detail from the general principles that have produced our existing central station, I asked the engineers of the construction bureau of the company with which I am associated, these questions:

1. What would be the cost of power in a station that you would build to-day to supply about 2000 h.p.

2. Suppose you had to supply the same at each of ten scattered points within a territory 100 square miles, what would the power cost from a big central station?

The point of asking for both figures from one office was to be sure that both were on the same basis: that if the cost of turbines, for instance, should be taken too low, or too high, or if the cost of labor were taken too high or too low, nevertheless the same basis would be used on both sized plants and would produce no error when comparing the two propositions.

There are, of course, two kinds of errors that we are subject to. If one man makes an estimate for both sets of conditions, then even if there are errors or omissions, as, for instance, if we have figured the price per ton of coal too high or too low, or if we have figured 10% depreciation against an actual 3 per cent, or have omitted taxes altogether, still the comparison is, on the whole, correct even if both sets of figures themselves are a good deal out of the way, since they would be out of the way by the same proportion in each case.

On the other hand, if instead of comparative estimates we take actual results in plants that have run long enough to give results, we find that the comparison is never on the same basis. One man has bought turbines when the manufacturer was willing to cut prices; the other has run into quicksand in his foundations or unusual labor troubles; and although the individual figures in each actual case must be much more correct than in the estimates, yet there is no question but what accidental items affect tremendously the actual costs in individual cases, so that the comparisons based on actual correct figures are often very erroneous comparisons.

For instance, published cost figures are sometimes what would be called the engineering costs, omitting several items that should be included in the real commercial costs before dividends would be declared, but if omitted items apply to both sets of figures, the comparisons are not seriously wrong. On the other hand, we know of hundreds of 2,000 horse power plants when the actual figures over a term of years show results much higher than in Mr. Main's plants, and higher than in some 1,000 horse power or even 500 horse power plants. We cannot use such actual figures for comparison, no matter how correct each set of figures may be, because they are not on the same basis and we cannot take figures for a few well-designed plants as representing real average conditions any more than the average central station can feel sure of operating at as low costs as the best central station.

Our engineers' figures, however, are on the same basis for

both small and large plants. I will not take time to present their figures in detail but they figured that ten plants of 2000 horse power each cost $980,790. per year to deliver their power. and one large plant to deliver the same power, including distribution expenses, $739,580. per year—a saving of 25 per cent.

No one should expect any other comparative results. When the Edison Electric Illuminating Co. of Boston owned plants of from 100 to 2,000 horse power capacity each in Somerville, Dedham, Milton, Newton, etc. it found it paid to abandon them and establish one big generating plant at L Street in Boston and distribute the power to outlying districts.

When the Pacific Mills in Lowell, or Swift & Company in Chicago, concentrate all power in one large power house instead of one plant for each building, it is because central station power is cheaper than small scattered plants.

It is safe to say that a good engineer who has a chance to make a saving for his clients would seldom advise a dozen small plants as against one large one.

Apparently, there can be but one answer to the question as to whether a central station or scattered plants are cheapest and yet plants such as Mr. Main has installed in his practice and even smaller ones, are still being put in occasionally instead of the user buying power from existing central stations.

The real question is not whether large stations are cheaper than small ones, but the question is: Why do not the present central stations take all the present business when it can so surely be supplied at a less cost to the community if supplied from a central station?

The question is: Why are any small plants left? The real question is not as to the facts, but as to the reasons why we do not take advantage of the facts.

Now the figures usually assumed as the cost of supplying power to the small plants from a large central station are somewhat different from the prices the central stations will actually quote. The question is, therefore, not whether central station power is cheaper than power of a private plant, but whose fault is it that there should be so much difference of opinion as to the actual cost in particular cases? In my opinion, both sides are to blame. The central station has, to a large extent, failed to realize its opportunity. Also, the builders, or rather promoters, of the small plants usually figure much too low for the real commercial cost, and all of us, even when we have thought

clearly ourselves, have failed to get the exact knowledge sent home to the general public.

Now why should the central stations, who are not making fabulous profits, insist on such high prices instead of giving the customer at least part of the advantage of the reductions in cost that everyone agrees ought to come with central supply.

The first thing is to analyze the actual central station figures and find where the money is going. We find on taking published figures of central stations certain large items that are nearly or entirely omitted by private plants. Billing and collecting is, for instance, a large item in central station costs.

The size of these items is obviously due to the number of small customers. On the other hand, with twenty large customers, or even one such customer, it would amount to something, yet it is practically negligible in comparison with the bills rendered. Again, for a few large plants we have figured 10 per cent loss from the central station while the actual central station of to-day reports 30 per cent. For a few large customers 10 per cent is correct and again the high figure for the existing central station is due to the number of small customers who use transformers at a poor load-factor. For a few large plants, we figure only a small distribution expense, while the actual central station spends far more for distribution than for manufacturing, and as before stated, this is because the existing central station has a lot of small customers.

The combination of big with little does not necessarily add to the cost of either and more usually saves on both. The wholesale department of Jordan, Marsh & Co., dry good merchants, is not handicapped by the retail store of the same company but the wholesale and retail departments complement each other. If a central station for a few large wholesale customers should add retail net-work and get enough income from the retail to pay all the additional costs, it would not add to the cost of supplying the wholesale, although the average cost per horse power delivered to all the customers might and would go up.

Up to within a very few years, central stations have had only a retail business, and have not realized that they did not increase distribution expenses proportionately by adding a few big customers. Up to within a few years central stations figured on their average costs of retail business and thought that the big business was a loss because it would not bring as much per kilowatt hour as their average costs. To-day, they are be-

ginning to realize that it is per cent on investment and not cents per kilowatt-hour that means profit; but business of to-day is the result of prices of three years ago; it takes time to develop. Even to-day, however, few central stations realize the field that they should cover. Unjust critics are to a certain extent responsible for this, as central stations depend on popularity. A central station making 5 per cent on its investment from the proceeds of retail business, seeing that a low kilowatt hour price to a big mill means a 6 per cent return on the investment for that customer and an accompanying later reduction in price to its small customers, hesitates to make the price necessary to secure the large customer because the big differential furnishes an apparent argument to those who claim that central stations are favoring large customers against the small, and 5 per cent with popularity is better than 6 per cent with unpopularity, even if in the latter case the small customer is getting his price actually lower.

Central stations have been weak in not analyzing their expenses properly, but the owners of small plants have likewise failed to analyze their expenses as between their plants and the rest of their business.

When a central station figures that doubling its kilowatt hours by selling ten million more to a single customer will add to its distribution expenses as much as if it sold them to ten thousand customers, it makes a very serious error. On the other hand, it is sure that every additional piece of business added adds something to the expenses all along the line; in some cases more, in some cases less. There are a great many expenses of a business that must be paid but cannot be said to be part of the cost of any particular portion. These are what are sometimes called the general expenses, but they often have other names. For instance, the salary of the president's office boy is not obviously part of the cost of unloading coal, and yet we know pretty well that if we should unload five times as much coal as we do now, the expenses of the president's office would go up.

The cotton mill seldom figures any of the interest on its floating debt against cost of power, and yet the money tied up in the coal pile must be drawn from somewhere and must earn its interest somehow.

Each item is in itself usually small, but in some isolated cases there are often extra expenses that run into big figures.

Once I prepared some estimates for one of the best engineers we have, one of the men who is now doing things rather than engineering them. He said to me, "Hale, your estimated figures are all right so far as they go, but remember that the expenses that really count in business are those that you don't figure on." In my own department I am always tempted to figure that when I add another salesman at $100 a month, I am adding only $1200 a year to my expenses. I have, however, taught myself to remember that he will need a desk, part of the office, rent, part time of a stenographer, office boy, etc., and these all cost money. A stock exchange broker once told me that when he hired a salesman, the commissions on the business the salesman brought in must be four times his salary, otherwise the salesman was really a loss.

Now, just as central stations have figured the costs of adding large customers to their retail business too high, so the mill in its analysis has failed to remember that its power plant involved other expenses besides those it figured on.

I am perfectly willing to agree that the figures which are presented in Mr. Main's paper are correct as far as they go. We have in Massachusetts 100 to 1,000 such plants as those of which Mr. Main has given an account. What has been the cost in others? The cost in a central station we *know*, and know for large stations and small stations. We have had bed-rock experiences for 20 years with no chance to draw on the general expenses of the rest of a mill. Any expenses which we forget to figure on come out of profits; but do you not suppose that if you got at a mill whose treasurer took a pride in his weaving-room and cared little about the expense of his engine-room that you would find a good deal more charged against cost of power than Mr. Main has given as the cost in the best plants?

To bring this out, take some of these estimates of cost and consider what a promotor says if he is asked to put in a plant and sell power at his estimates. Suppose he figured 6 per cent on the money; 6 per cent is a good return year in and year out and if the promotor's figures are for the actual costs, they should show profits that would give more than 6 per cent just as often as they would show losses. But we all know what the promotor says: he is not in the business of selling power and would not want to risk his money. He knows that before the work is done there will be all sorts of extra expenses of the kind he has not figured on. He knows that if the plant is run in

connection with a mill, or hotel, by anyone that is not in the power business, that all these extra expenses will come out of the general profits of the other business, while if the plant is run independently and on its own basis, it would have to stand its share. Still these othei expenses must be paid before the dividends. The owner of the business usually realizes this, though not in full degree. He always says, " I am perfectly willing to pay 10, 15 or 25 per cent more for central station power than it would cost me to make it myself ". If the costs he is thinking of were his real costs, this would be foolish, but what he really means is, " In addition to the costs that my engineer or bookkeeper figures for me, I must add 10, 15 or 25 per cent for what they do not figure on ".

Now, if the engineer has included all the items, *viz.*, interest at the same rate of profit the owner wants on all his busines depreciation figured not on the time the plant might last but on the date when he will scrap it, taxes, insurance, coal, water, labor, repairs, rent, removal of ashes, loss due to noise, loss due to vibration, loss due to dirt, loss due to non-flexibility, loss due to extra cost of running overtime, extra cost for superintendence including the time spent in hiring and discharging engineers, purchasing coal and supplies, checking records, etc., etc. (these all should be added), and if after *all* the expenses are included the plant shows a less cost than purchased power, it should be put in. When an owner says he will pay 20 per cent more for purchased power than it would cost him to generate it for himself, he is really saying, " My engineer is sure to omit 20 per cent of the real costs;" and just as the actual central station of to-day has a tendency to figure costs of supplying big power too high, the actual isolated plant of to-day figures its costs too low.

The projectors of isolated plants often lay stress on the special advantages of a separate plant for some particular case. This is usually in connection with the use of exhaust steam. One of the isolated plant advocates told his client that he could use his steam three times; first, for power; second, for heating by exhaust steam; and get a third supply of heat for evaporating sugar or in chemical processes.

There is no question about the theoretical advantage of using the exhaust steam for heating, but if the practical advantage followed the theoretical then the central stations should be putting down small plants in the centres of cities and selling steam heat in local blocks. If the central stations find this does

not pay, and practically every one of them has tried it at some time or other, then the chances are that it usually does not pay. The same idea applies to many of the other special cases.

A further difference between a small plant and a central station is that there is an actual difference in the thing supplied in two very important ways. One is quality of service. Theoretically, a small plant can often give as good service as a large one. Practically, the large one gives wool against cotton in many ways. The steadiness and reliability of the power in every way is, as a matter of fact, much greater for central station power. This costs more and is worth more and often the central station has not any poor service to sell at a low price. This is a special condition that is really more frequent than the question of steam heating. A business that is fully satisfied with cheap and irregular power at a low price can often make that quality of power itself better than to buy a good quality of power from the central station.

A second is that the isolated plant supply is inflexible but the central station supply is flexible. An isolated plant, if figured on depreciation of 3 per cent, must be used a quarter of a century. Even at 10 per cent, it must be used a long time; and, more than this, no plant is like the one horse shay, it can *never* be discontinued without a loss. On the other hand, central station supply in many cases can be discontinued at the will of a purchaser on a moment's notice. In other words, with central station supply, the purchaser is free; with a plant he is tied like a serf to the investment he has put in.

It is true that this freedom for the purchaser can only be given at an expense to the central station. When the central station must be prepared to lose a customer at a moment's notice, or a month's notice, it cannot make its arrangments as economically as if it counted on running along exactly the same year in, year out, as the mill that has its own plant must do in order to make the plant pay. Part of this condition can be and is taken care of by long-time contracts. If a central station can figure that its investment for a particular customer will be used for all time and will not be discontinued at some definite or indefinite date, it can supply power more cheaply. On very large business, it must get this assurance by long-time contracts; on small business by its own judgment of the future; but even with the longest and strongest contracts made with the central station, the mill is freer when purchasing power than with its own plant, since at

the end of the contract it discontinues without loss, while with a plant of its own it can never discontinue without loss. Perhaps in special cases this freedom may not be worth anything, yet it is safe to say that in general the central station sells better power and allows more freedom than the isolated plant can give.

To summarize:

1. Central station power can, except in very unusual and special cases, be supplied more cheaply than when a man in another business attempts to make power as well as to carry on his own business.

2. Central station power is practically always better and gives the private owner more freedom and flexibility than when he ties himself to his plan.

3. The existing central stations have in the past figured the cost of their power supply in large lots too high, and have unconsciously hurt themselves and the public by attempting to charge large customers too much.

4. When central stations have made proper prices, the people who do other kinds of business have hurt themselves and the public by figuring their own costs of power too low and not charging their own time and general expense against the added business responsibility of the plant.

In future, the central stations will come closer to the other businesses; all will get together and pull together, and an isolated power plant will, before many years, be just as scarce as an isolated plant for making gas is to-day.

A paper to be presented at a joint meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, Boston, Mass., February 16, 1910.

ILLUMINATION FOR INDUSTRIAL PLANTS*

BY G. H. STICKNEY

The problems of industrial illumination include the lighting of offices, yards, elevators, stairways, and other accessories, but it is the purpose of this paper to treat principally of artificial illumination for the actual processes of manufacture.

Electric light is being adopted generally as the standard of the best practice, furnishing the safest, most convenient, and usually the most economical illuminant available, therefore this paper will treat of electric lighting only.

Value of good artificial illumination. All industrial processes are subjected to a close cost-scrutiny. Pressure is placed wherever it seems possible to reduce cost. The lighting bill, holding as it does an indirect relation to the resulting product, is often discriminated against. Although it is seldom practicable to estimate accurately the relative values of different degrees of illumination, it is well known, however, that an average workman can do more work and better work with an illumination of suitable intensity than with a weaker light. Figures have been published which show the relative rate of production by daylight and by artificial light in particular installations. In every case the superiority of daylight has been startlingly demonstrated. Unquestionably in the majority of manufacturing plants to-day, raising the standard of illumination would justify its cost, in the improved quantity and quality of production. Many factories are operating by old and inefficient methods, where the use of modern apparatus and methods would actually show a reduced operating cost with improved illumination.

In revising the lighting of plants to take advantage of new developments, the manufacturers have in a number of instances

[*This paper will be presented under the auspices of the Electric Lighting Committee.]

expressed surprise at the marked improvement in production due to the better illumination.

The workman. The operative is an important factor for consideration in any lighting proposition. Since the light is provided primarily for his use, in order that he may perform his work advantageously, it follows that it should be suited to his needs. To be satisfactory the illumination should enable the workman to perform his work quickly and well, without excessive eye-strain. The illumination can increase his efficiency by making him at ease with his surroundings, or it can render him dissatisfied.

It is seldom practicable to equal daylight, and therefore it is usually advantageous to call as little attention as possible to the artificial lighting. One of the serious objections to placing a small portable light under the control of the workman is that he is inclined to experiment with it, not only wasting his time, but often placing the light so as to produce a glare in the eyes of his fellow, workman or himself. Such an arrangement is soon followed by eye-strain, and the workman feels a desire for more light. An increased light only makes matters worse, and at the same time calls for a higher current consumption. We have revised such installations when it was possible, cutting the current consumption in two, by going to general illumination and still providing ample working illuminations.

Such a change is usually resisted at first by the workman, partly because the strained condition of the eye makes it require more light for clear vision, and partly because the workman thinks an inherent right is being taken from him. If the change can be made diplomatically, perhaps providing additional intensity for the first few days, it is not unusual that a considerable reduction can be made, and at the same time a light furnished which is really better for the employe. In making such a change the operator should understand that the new system is an accepted success elsewhere. If it is treated as an experiment and the workman's opinion asked, he is apt to become over-critical.

The building. The lighting system in any building or room should be arranged so as to fit the conditions. Likewise the building should conform as far as possible to the requirements of good lighting. The finish of a room affects the efficiency of a lighting installation considerably. A dark finish is rich and pleasing to the eye, but in a workroom it is often extravagant. Whitening the walls, pillars and ceilings of a room will produce a remarkable increase in the effectiveness of the light.

A high-studded room sometimes requires more power to light than a lower room, but it permits the use of larger units with wider spacing. This is desirable from an installation and maintenance standpoint. It is common practice to space lamps one and one-half to two times as far a part as the height above the work.

Especially in large rooms the use of low glaring lights should be carefully avoided, as the lamps brought together by perspective are distressing to the eye. The higher the lamps are hung the less the necessary precaution to avoid glare. Modern factory buildings have as large window areas as possible. While this construction increases the effectiveness of daylight, it requires a higher intensity of artificial illumination. This is partly because operators accustomed to strong day illumination require relatively strong artificial illumination, and partly because of the loss of the artificial light through windows. Where conditions permit the use of white curtains, much light can be reflected back and retained in the room.

It is well in arranging lamps in a room to favor those parts which have the best daylight, because in arranging the work the processes requiring the most light are located near windows.

General local illumination. There are two principal ways of lighting a room; namely, by local illumination and by general illumination. Where the former method is followed, a small lighting unit is placed at each point where particular illumination is required, the remaining parts of the room depending on stray light or a low general illumination. For general illumination, the room or section is lighted by systematically placed units so arranged that all parts receive approximately the same illumination.

Relatively large lighting units are used, depending in size upon the dimensions of the room and degree of illumination required.

With general illumination the arrangement of lamps, being independent of the detail location of machinery, does not require change with rearrangement of the work. General illumination does away with temporary construction and unsightly drop-cords, and the accompanying high depreciation, and, in many cases fire-risk.

The use of drop-cords among stock shelves is especially to be deprecated, on account of the tendency to put the lamp down where there is danger of causing fire. With properly

labeled shelves, a permanently installed lamp above the aisle will provide necessary illumination. When it is necessary to look under the shelves, a hand mirror can be used.

When lighting processes in an open room, general illumination can be used economically where work is concentrated, but where there are just a few widely separated points that require light the method of local illumination will be the cheaper. The choice between the two methods often depends upon the process. General illumination gives a softer and better diffused light, but will not furnish light in a deep boring as readily as a specially placed local lamp. General illumination permits the use of the most efficient illuminants, with least wiring and maintenance expense.

Processes. In order that a process may be properly illuminated it is necessary that it should be understood by the illuminating engineer. He must know how the light is to be used, in order to determine intelligently the most desirable intensity, degree of diffusion, direction, and color of light.

In a textile mill, for example, the weave room is more exacting in lighting requirements than the spinning and carding rooms. Colored goods require more light than white goods. Different types of looms have different requirements as to direction of light. In high-grade work where there is shading of colors, white light is demanded.

A very exacting problem in color lighting was for the process of shading of buttons in a large button factory. The manufacturer who had built up his reputation on careful workmanship, was sorting buttons in from 14 to 17 shades, when the ordinary observer could readily detect only 5 or 6 different shades. After experimenting with various so-called white lights, he had practically given up the possibility of illuminating this process by artificial light. With high amperage direct-current arc lamps, equipped with inverted diffusers and large opal outer globes, specially placed over the work table, satisfactory results were finally obtained. The problem was complicated by the glossy surfaces of some styles of buttons, which demanded extreme diffusion and rifted surfaces of other buttons which demanded suitably directed light.

An interesting intensity problem was presented by a leading rifle manufacturer, who was unable to obtain suitable artificial illumination on the targets of a 220-yard testing range. Measurements showed that the marksman required 25 to 30 foot-candles

for satisfactory work. Daylight intenstities were running as high as 60 or 70 foot-candles, but the artificial illuminants as installed were giving only about 6 or 8 foot-candles. An equipment which gave about 30 foot-candles was installed and gave immediate satisfaction. Later they decided to eliminate daylight altogether, as the steadier artificial light gave more uniform results.

In machine shops, general illumination can ordinarily be used to good advantage, although some special operations require local lighting. Such local lighting is sometimes provided by loaning extension lamps to the workmen on check, after the practice followed with tools. This practice is often used for automatic machinery, where special light is required for setting up, though a low general illumination is suitable for regular operation. Ordinary machine-shop work requires about 3 foot-candles, though for rough work 1 foot-candle is often satisfactory, while for fine work 6 or more foot-candles may be required.

The presence of many overhead belts makes the elimination of shadows with general illumination more difficult, and also is apt to be destructive to drop-lights. Modern shops use as few overhead belts as practicable.

In a large clothing factory recently completed remarkably satisfactory results are being obtained by general illumination from tungsten economy diffusers. This suited all processes, the number and size of lamps in each diffuser being varied to meet the intensity requirements of the different departments. Some difficulty was found in seeing the seam at the middle point of a sewing machine when working on black cloth. This ordinarily would require a local lamp. Preliminary experiments with a local reflector for casting a special beam of light at this middle point indicate that this form of local lighting can be satisfactorily applied.

In drafting rooms at least 6 foot-candles should be provided on the drawing board. The selection between general and local illumination depends upon arrangement of the room and other conditions. Where local lighting is used lamps should be shaded to cut off glare, and if possible located out of the draftsman's reach over the table a little to his left.

Circuits. The circuits for feeding factory lighting are usually determined by the central station current available, or the requirements of the electric motors in the plant. Either direct or alternating current can be used to equally good advantage for

lighting, except that arc lamps do not give a steady light on 25-cycle circuits. Wherever possible the voltage of the lighting circuit should be between 100 and 125, as the most efficient lamps are more readily applied to these voltages. A 220-volt, 3-wire circuit is commonly used to good advantage.

Where motor service is intermittent, affecting the voltage regulation of a local circuit, it is desirable to separate the lighting and power circuits as far as possible. In some of the largest textile mills in New England, where the supply is alternating current, the general illumination is provided by means of series direct-current arc lamps. This furnishes a white light with remarkable economy of current consumption and maintenance. Series circuits in general, however, should be avoided except when they can be safeguarded.

Careful study is usually warranted in dividing up circuits and locating switches to accommodate requirements of particular processes.

Lamps. The lamps available for industrial illumination may be considered under two classes; namely, incandescent and arc lamps.

The principle types are as follows:

INCANDESCENT	ARC
Carbon.	Enclosed carbon.
Glower.	Intensified carbon.
Tantalum.	Mercury.
Tungsten.	Luminous, magnitites.
	Flame carbon.

None of these lamps is suitable for all conditions of lighting. It is often desirable to use several types in different parts of the same plant.

Incandescent lamps are usually made up as small units, but may be combined or grouped so as to form larger units.

The carbon incandescent lamp has a high specific consumption and is economical only with very low price of power, or in small portable units. As is will stand rougher handling than any of the other forms, the carbon lamp is ordinarily used with extension cords.

Tantalum lamps are finding a considerable use in manufacturing plants, especially where direct current is available.

The tungsten lamp has practically revolutionized commercial lighting and is now being extensively adopted in industrial light-

ing, especially in textile mills. It is by far the most efficient of the incandescent class, and while the maintenance seems high in some cases, it is being rapidly reduced with the progress of development. Where lamps are protected from excessive vibration or shock, the tungsten is giving an exceedingly long burning life. In choosing between tungsten and tantalum, the cost of current and the size of unit desired are usually determining factors. Tungsten lamps are used singly or in groups with metal diffusers or prism glass reflectors. Where there is considerable building vibration, they are provided with spring suspensions. In equipping and arranging lamps thought should be given to determining where the light is wanted and what degree of diffusion is required. Where there are dark ceilings, all upward light is wasted, as far as lighting the process is concerned.

Enclosed-carbon arcs, both direct and alternating current, are used to a large extent in industrial lighting. They are efficient as large units and have a very low maintenance cost. For the higher grades of lighting they are often equipped with diffusers to soften the light and direct it downward at desirable angles.

The intensified enclosed arc lamp is now available for direct-current multiple circuits. It is more efficient than the corresponding capacity of the enclosed arc lamp. This lamp and the high current enclosed arc lamp are superior to all others for color selection.

The flaming arc lamp, using the so-called yellow carbons, after several years use principally as an advertizing light, is now being used to a considerable extent for the lighting of foundries, machine shops etc., where the rooms are high, and where it is desirable to hang lamps above the crane.

The characteristic distribution of this lamp as now built is particularly adapted to high buildings since the maximum light is thrown directly downward. The light is very powerful, and suited for lighting large areas when hung high. When placed too low the light would be glaring and inefficiently distributed.

Future progress. The remarkable developments of the last few years, and the remoteness of ideal efficiency, give promise of further development and improvement in illuminants. The importance of these developments in cheapening and at the same time improving the artificial illumination of industrial processes behooves the manufacturer to keep abreast of the times. It should be borne in mind that the first cost of almost every type

of electric lamp is relatively small, as compared with the cost of a year's operation, so that the user can afford to take advantage of the developments, even to the extent of throwing out his old lamps and putting in new ones at reasonable intervals.

An estimate recently made in store lighting showed, that by capitalizing the saving of the next seven years the storekeeper could afford to throw away his present lamps and install a more modern type, even if he had to pay about 10 times the market price for the new lamps. There are many similar conditions existing in the field of industrial illumination.

A paper to be presented at a joint meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, Boston, Mass., February 16, 1910.

(*Subject to final revision for the Transactions.*)

THE REQUIREMENTS FOR AN INDUCTION MOTOR FROM THE USER'S POINT OF VIEW

BY WALTER B. NYE

In attempting to discuss this problem I have a natural hesitation, owing to my lack of technical knowledge, but I nevertheless appreciate that possibly the point of view of that large class which pays the bills, and to which the motor is but a means to an end, may be of some interest to the designing and constructing engineers.

My experience with induction motors has been mainly in sizes ranging from 50 to 500 h. p., running 24 hours a day six days a week, and the prime requisite from a manufacturer's point of vew is *continuity of operation*. I will not say that to this everything else must be subordinated, but in any industrial plant continuous operation must be maintained. To insure this the motor must be of a rugged mechanical design, with ample bearings; capable of withstanding reasonable overloads for a considerable period without undue heating; must be accessible so that it can be easily cleaned, and, in case of trouble, be easily and quickly repaired; and the motor must be able to hang on and not "pull out," even under great variations in voltage. Efficiency, power-factor, and starting torque are all worthy of consideration, but are not, to my mind, as important as the points above mentioned.

To secure continuity of operation and ease of repair, form-wound impregnated coils should be used. Impregnation of coils is suggested because in many industries motors are subjected to moisture, steam, fumes, either acid or alkaline; dust, which may be organic, and which by its decomposition effects the insulation. Impregnation renders the coils much more immune to these conditions.

However good the motor may be, sooner or later repairs will be necessary, and in that case a form-wound coil is much more easily put in place than any other type. Coils should be made accurately to size, so there may be no difficulty in placing them in the slots, and there should be good mechanical connection between coils, as lack of this often leads to open-circuiting. It is also desirable to have a good terminal board, and preferably flat, flexible copper leads, so as to do away with soldered or screwed terminal connections. It would also be well to use particular care in the quality of the insulation on the copper bars in the rotor where they pass through the slots, as this would reduce the amount of labor in repairs. It is to be hoped that some better scheme may be devised for connecting the conductors to the outside rings, as bolts corrode, and it is seldom possible to remove them without twisting them off, which again occasion delay.

Bearings should be long, well designed, and filled with the best quality of babbitt. Great care should be given in designing the channels for the oil-rings to travel in, so there may be no chance for the ring to catch; and the sight-feed or overflow pipe should be piped away from the bearings, so that inspection may be given it regularly.

Shafts should be stiff, and the motor so designed as to permit of considerable overhang of the driving pulley. There is a tendency on the part of designers to increase the diameter of the driving pulley, narrowing the face in order to reduce the overhang; but at the speed at which most motors run, these large driving pulleys occasion difficulty in getting down to such speeds as are common in mill practice. In fact, the motors which so far have come under my notice have practically all had to be equipped with smaller, wider pulleys than those sent with them. This condition might as well be realized, and the motor designed for this service.

My experience has been mainly with a group drive, hence there is a chance of continual slow growth in the power requirements, and for that reason the motor should be capable of standing up to the load, even if in excess of its name-plate rating. A motor, therefore, should be designed to stand at least 25% continuous overload wthout undue heating, and should be so designed as to permit of good ventilation and a ready access of the air jet in cleaning out.

Controllers, and particularly switches, should be of the oil-

immersed type, doing away with fuses, thus meeting the requirements both as to fire hazard and to life, from contract with the average open-jaw switch. Experience shows that auto-transformers for use in connnection with the induction motors furnished have almost invariably been too small, and after considerable trouble in endeavoring to start the motor, it has been necessary to secure larger ones. Designers may well consider this point and be more generous in their provision of capacity in these most necessary appurtenances.

In view of the various sugggestions which have been made, the motor manufacturer may well say that to meet these conditions he will be obliged to increase the price of his motor. I believe to-day that motors have been re-designed to a point where there is almost no margin for the user, and as the motor is but a means to secure a desired result, the user can well afford to pay a little more for a well designed motor containing some reserve in capacity and ability to stand hard usage, and it will be found to be a paying investment in the long run.

A few words may not be amiss here as to the method of application of induction motors to the work in hand. In the business in which I am interested (paper manufacturing), we have not thought it wise to take up the application of the individual motor to the individual machine, although this has been developed quite fully by the electrical engineers. We have so far made use of group-drives, so arranging the groups as to make use of but a few standard sizes, of which we always keep one or two in reserve for use in case of emergency. The standard group might be said to be that driven by a 100 h. p. motor, of which we have twenty, and for which we constantly hold two extra motors in reserve, one of them on trucks ready to be hurried to any point required. In this way, should anything occur to a motor, it can be removed and a new one slipped in its place, with the loss of but a few moments, and the repairs made at the shop at leisure. This same practice holds good for all sizes up to 150 h. p., above which this scheme is not practicable.

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

(Subject to final revision for the Transactions.)

A PRACTICAL METHOD OF PROTECTING INSULATORS FROM LIGHTNING AND POWER ARC EFFECTS

BY L. C. NICHOLSON

The problem of adequately protecting a high-tension transmission line against injury by lightning is an important one. Various solutions have been proposed, but it is generally conceded that complete protection of high-tension porcelain insulators from destruction by lightning effects has not been attained. Grounded overhead conductors, relief gaps on insulators, lightning rods supported on the transmission line structures or on separate structures alongside, and station-type lightning arresters at points particularly exposed, are some of the principal preventive devices employed, any of which serves to ameliorate conditions, but none of which affords ideal protection to the line.

The 60,000-volt transmission lines of the Niagara, Lockport and Ontario Power Company from Niagara Falls to Syracuse and other cities in western New York, were placed in operation in July, 1906, just in the midst of the lightning season, and without any of the usual methods of line lightning protection. Troubles developed which, though not unexpected, proved of serious consequence to the successful transmission of power during lightning storms. There was little opportunity in that season to adopt any corrective measures, either experimentally or otherwise, but in the following years the company has exerted every effort to ameliorate these troubles.

The experience of four years has served to indicate something of the real nature of lightning effects which result in insulator failures, and has led to the development of an inexpensive and efficient means of protection. The object of this paper is to re-

late the experiences and experiments leading to the protective measures finally adopted, which from one summer's trial appear to be sufficient.

This plant was thoroughly described by Mr. Ralph D. Mershon in a paper presented at the Niagara Falls Convention* June, 1907. For purposes of reference, Fig. 1 shows the extent and description of lines, the connection and approximate capacity of the stations.

Figs. 2, 3, and 4 show types of line structures employed. In all cases insulator pins are of steel and are grounded.

Fig. 5 shows the principal insulator used, and, with the exception of a few smaller ones of the same general design, the only type of insulator employed until 1909. This is known as the "3-part main line" insulator. Its principal dimensions are:

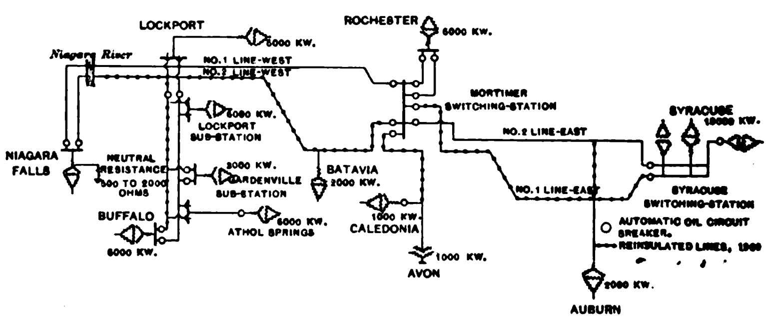

FIG. 1.—Diagram of transmission lines and stations—1909

Diameter of headpiece, 14½ in.; diameter of intermediate shell, 13 in.; diameter of center shell, 11 in.; length of intermediate shell, 12 in.; length of center shell, 17 in.; height over all, 19½ in. The dry flash-over voltage, that is, the voltage which will cause a flash-over when the surface is dry and clean, is 195,000. The wet flash-over voltage at 1/5 in. per minute precipitation at 45 degrees is 120,000.

Electrical tests on these insulators before their erection on the line consisted of 75,000 volts, three minutes on each part before assembling. The complete insulator was not tested after assembling.

During 1906 only one line was in service to various points. By the beginning of the lightning season of 1907 the second (duplicate) line was placed in service, making a total mileage

* TRANSACTIONS A. I. E. E., Vol. xxvi part ii, p. 1273.

of 400, containing 7000 structures and 23,000 insulators. Except for the addition of a few single branch lines from time to time, the lines have been virtually the same for three years.

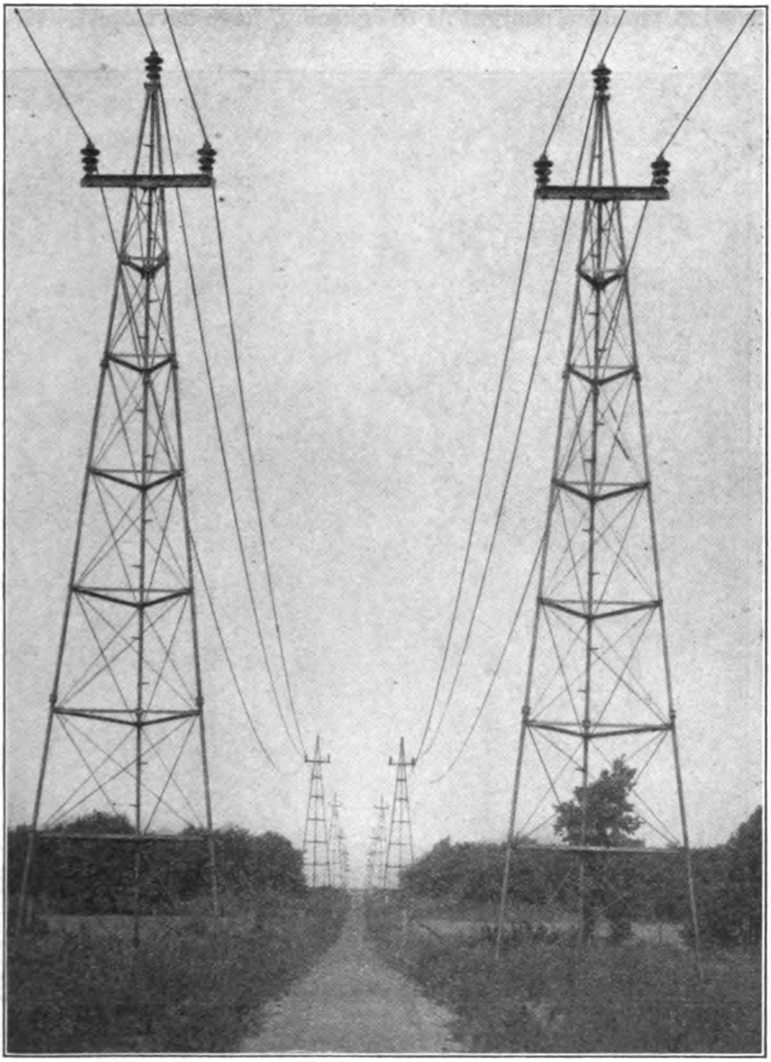

Fig. 2.—55-ft. tripod pipe towers

Switching facilities and general operating conditions, however, have been constantly improved. Since early in 1908 automatic oil circuit-breakers have been used in the duplicate lines at all

important stations and paralleling points, making possible automatic sectionalizing of lines and a quick restoration of power in case of an interruption.

Lightning troubles have been entirely confined to the line. No station troubles, chargeable to lightning, have developed.

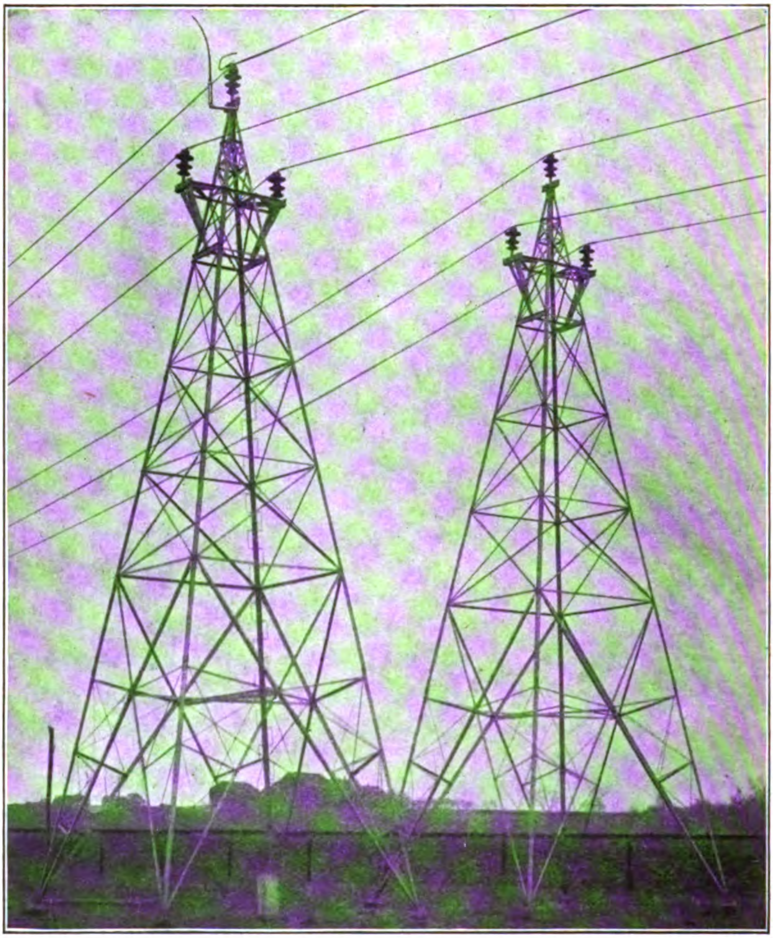

FIG. 3.—55-ft. structural steel towers, showing a relief gap, as used in 1907

Experience clearly shows that lightning in the vicinity of the line induces high potentials between the line conductors and earth. This potential causes one or more insulators in that immediate vicinity to flash over or puncture, or to be shattered in some part or parts, even though no flash-over or

puncture occurs, or to be shattered by the power arc following the initial flash-over or puncture. These various causes intermingle their effects so as to obscure the first cause. Thus it has been found that insulators may be shattered completely either by pure lightning stresses, or by the heat of a power arc

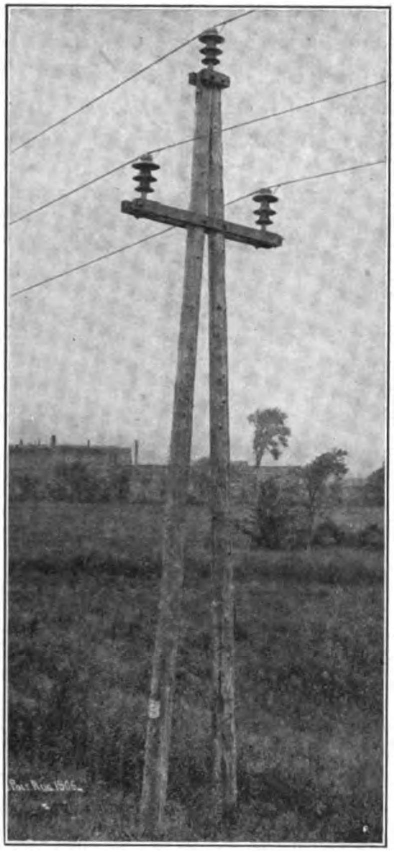

FIG. 4.—35-ft. wooden A-frame structure

which follows the initial discharge from conductor to pin over the outside surface. Moreover, an insulator may puncture by lightning, and subsequently be shattered by the heat of the power current passing through the puncture, in which case it is impossible to say whether the puncture preceded the shattering or vice versa. A fairly concise idea of the nature and mag-

nitude of the destructive forces may be gained by a study of the broken insulators in place.

Fig. 6 shows a collection of twenty derelicts, resulting from a single severe storm, and gives a fair representation of how insulators are destroyed by lightning in combination with high-power effects.

The usual case of line disablement involves a single insulator, which is either punctured from the cable or tie-wire to the top of the pin, or, being sufficiently strong to resist puncture, is broken by the flashover arc. Frequently several neighboring insulators are more or less damaged

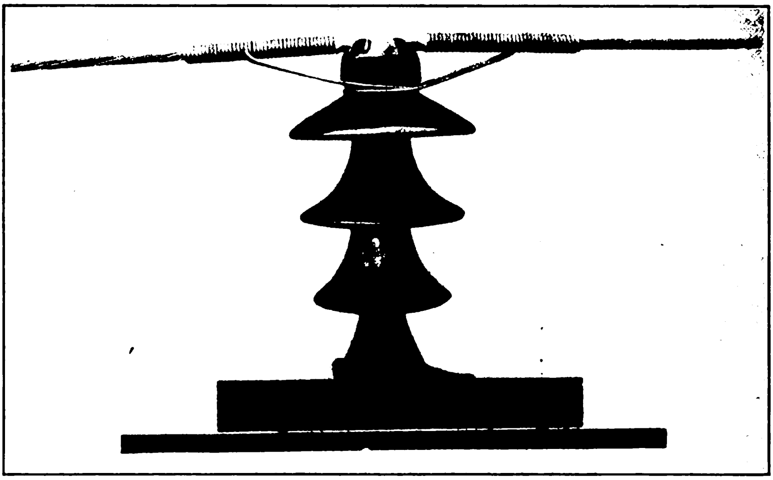

FIG. 5.—3-part main line insulator

by what appears to be the effect of sudden mechanical forces which shatter or break the shells very much as a hammer blow would destroy them.

Extreme cases infrequently occur when many insulators in a restricted locality are entirely destroyed. Such disturbances usually center at a particular line structure on which all the insulators may be entirely destroyed, and one or more insulators on several adjacent structures in each direction destroyed or injured, the injury decreasing in severity away from the focus. Even in the most severe cases, however, the entire effect is confined to within 2,000 feet of the line. Such accidents are attributed to direct strokes on or very near the line. The mechan-

ical forces exerted on insulator parts in such cases appear to be enormous, breaking the porcelain into small bits of irregular and curious shapes, and distributing them over the right-of-way for several hundred feet. Fortunately these extreme cases are of rare occurrence and do not enter largely into the lightning protection problem.

Just where direct stroke effects leave off, and just where induced potential effects begin and end, is, of course, indefinite. It is definitely known that a stroke 500 feet distant may cause a flash-over or puncture. It is thought that disturbances may be felt from bolts 2,000 or 3,000 feet away, this being also deter-

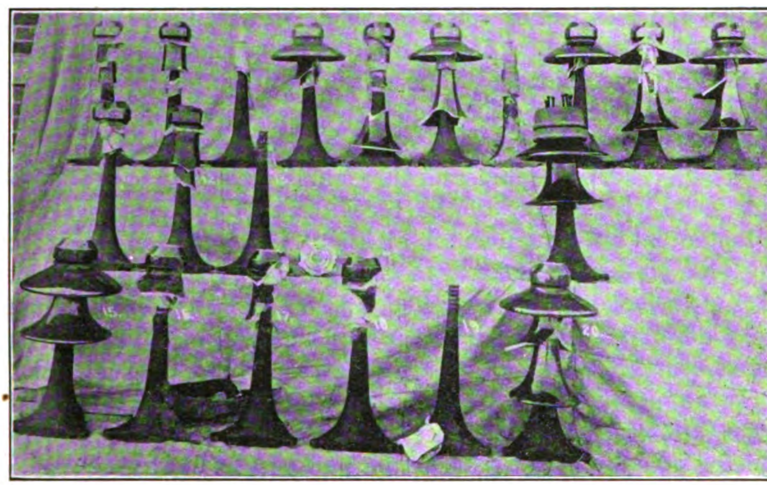

Fig. 6.—Insulators removed from the line after damage by lightning and power effects

mined by the size of the discharge, and perhaps by electrostatic conditions in general.

The insulator problem as outlined above presented itself by the end of the lightning season of 1906, although at that time its nature was not appreciated as fully as it became later in the light of the subsequent experience. Thirty-five insulators were disabled by puncturing or shattering, out of a total of 12,000 installed. These breakages occurred on eight different occasions and consequently caused as many extended interruptions to parts of the service. In addition, there were ten momentary interruptions caused by short-circuits or grounds which tripped the controlling circuit-breaker, but did not disable the line.

Analysis of the insulator failures with respect to their location showed a very remarkable result. The number of insulators disabled on the top wire was four times the number disabled on a single side wire, or twice the number disabled on both side wires.

This result formed a basis for corrective measures which were taken previous to the lightning season of 1907. These devices consisted of relief gaps installed on insulators at regular intervals on the top wire of both duplicate lines, and the installation of high resistances in the neutral earth connections of star-connected transformers. Fig. 3 shows the type and construction of the relief gap which was employed.

These gaps were spaced 2200 feet on approximately 240 miles of line and 4400 feet on 100 miles, while on 60 miles no gaps were installed. At the time of selecting these spacings there was very little data for guidance. The only definite information available was that during 1906, before the lines were used, insulators were destroyed within a mile of a point where all three conductors were short-circuited and thoroughly grounded. The 2200- and 4400-foot spacing of the relief gaps on the top wire was adopted in an experimental attitude, the intention being to increase or decrease these distances as future experience dictated. The width of gap first adopted was six inches, corresponding to a discharge voltage of 70,000 volts, depending more or less upon weather conditions. This was also a subject of experiment.

It was intended by proper spacing and setting of the relief gaps, to limit the maximum possible voltage between top conductor and earth to less than the puncture or flash-over value of the insulators, and thus prevent the failure of insulators on the top wire due to the usual lightning effects. It was also expected that when discharging through the relief gaps, the top conductor would act to some extent as an overhead grounded conductor, and in this way afford some protection to the two side wires. An adjustable concrete resistance of 500 to 2000 ohms was connected in the neutral earth connection of the sending transformers, and 5000- to 10,000-ohm resistances at five different sub-stations in the neutral earth connection of star-delta connected receiving transformers. The purpose of installing these resistances was primarily to limit the discharge current to earth from the top wire through the relief gaps to a value which would not disturb operation, and the arc of which would quickly follow up the horns of the gap and discontinue. In the same way it was thought that these resistances

would limit the power-current over an insulator containing no gap, in the event of a flash-over, to a value which would not work such havoc to the insulators as had formerly occurred when operating the system with thoroughly grounded neutrals. The 5000- to 10,000-ohm sub-station resistances were, of course, not necessary to attain the end sought. They were installed as a precautionary measure against abnormal potentials which might accompany grounds on the system. Their use was later discontinued, all neutrals except that at the generating station being insulated.

The operating results of the lightning season of 1907 did not fully justify the use of the relief gaps from a theoretical standpoint, and showed them to be rather an objection than an advantage from a practical operating standpoint.

It was early apparent that the gaps perfectly protected the insulators containing them, but that their protective influence was felt very slightly a short distance away on the same conductor, and was not felt at all on the two lower conductors. This was true with gaps set as low as 4½ in.

The following tabulation shows the season's results:

	Insulators disabled on top wire	Insulators disabled on both side wires
At a relief gap..............	0	6
220 feet from the nearest gap.	2	3
550 feet away...............	15	17
1100 feet away..............	11	13
2200 feet away..............	4	1
On a 60-mile section containing no relief gaps..........	9	5
	—	—
Total..................	41	45
Grand total.............		86

Insulators on line—23,000.

Relief gaps on line—750, approximately 25 per cent of which discharged one or more times.

These results demonstrate the extreme localization of lightning effects and the difficulty with which the charges travel along a conductor.

It appears from this table that the net effect of the use of the gaps was to save some insulators on the top wire. The number

of line breakdowns was not reduced, while voltage disturbances and momentary interruptions were numerous. For this reason the relief gaps were removed before the lightning season of 1908. The grounded horn was left in place to act as a lightning rod. The concrete neutral resistance at the generating station was retained to prevent short-circuits between any one phase and ground.

A study of the insulator failures of 1907 showed that the majority of them were due to puncture, usually from the tie-wire in the neck to the top of the pin. A few punctured vertically from the cable to the pin. Approximately 25 per cent, and perhaps more, were shattered by power arc following a complete or partial flash-over. Comparatively few, it is believed, were shattered by direct stroke, although about 40 were injured by lightning stresses, but were not incapacitated thereby.

In view of the large proportion of punctures, it was decided to apply high potential to the lines and to weed out the weak insulators. This proved to be a slow and expensive process, so that very little was accomplished before the advent of lightning in 1908. A three-minute test of 100,000 volts to ground was applied to 109 miles of line containing 4000 insulators, and resulted in the puncture of 80.

These tests showed what there was already good reason to suspect, *viz.*: that the insulators were not tested sufficiently before erection, and that many of those on the line could not resist lightning stresses, and some were liable to fail from abnormal voltages incident to operation. As stated above, the insulator parts were tested to 75,000 volts each, but no test was made on the assembled insulator.

The lightning season of 1908 was a particularly severe one, resulting in the destruction of 226 insulators and the injury of 100 more.

The failures may be classified approximately as follows:

1. Punctured:

Top wire	75
Side wires	39
Total	114

2. Shattered by direct stroke:

Top wire	22
Side wires	9
Total	31

3. Shattered by power arc, following flash-over:

Top wire	56
Side wires	25
Total	81

The 100 insulators which were injured were damaged by lightning stresses, or by power arc effects. They were still operative, however, and were replaced at convenience.

The lesson of the year was not new, but it showed more forcefully than had been realized before, that even if all insulators were capable of resisting puncture, they would continue to be shattered by a power arc following a flash-over. It was argued that by the proper testing of all insulators puncture could probably be prevented, but the fact that such a large number had been already destroyed by flash-over gave little reason to suppose that insulator losses and line interruptions could be materially reduced by providing puncture-proof insulators. They must be also fire-proof.

The only practical way of making the insulators puncture-proof was to remove them from the line, test each one to its dry flash-over voltage and return the perfect ones to the line. There was some question as to whether or not such a test would be effective, since an insulator which would flash over under 25-cycle voltage from a testing transformer, might puncture under the sudden attack of a lightning shock. However, the fact remained that insulators, presumably sound and dry, had flashed over in service because of lightning, rather than puncture, and this justified the belief that a 25-cycle dry flash-over test was sufficient. Subsequent experience has verified this conclusion.

A device for rendering insulators fire-proof, or rather proof against injury by power arc in the event of a flash-over, was developed to meet an obvious need. As shown by Fig. 7, this device consists of two metal rings concentric with the insulator, a lower one which is situated near the base being considerably larger in diameter than the insulator parts, and supported by grounded metal risers attached to the pin; and an upper one somewhat larger than the neck of the insulator, just opposite the tie-wire, suspended from the transmission cable, and electrically connected to it. Details of construction are evident from the figures.

These rings serve as electrodes, to which the power arc automatically transfers immediately after its formation between

the tie-wire and pin, over the surface of the insulator. When holding between these rings, the arc is removed sufficiently from the insulator to prevent injury to the porcelain by heat.

It was determined experimentally that the intense and concentrated heat at and near the ends of a large power arc is largely responsible for the damage wrought. This is particularly true of the lower terminal which passes up the pin to the heart of the insulator and shatters it. In other words, the insulator is broken from the bottom upward, by the lower end of the arc. The upper terminal, located on the tie-wire, is not so destruc-

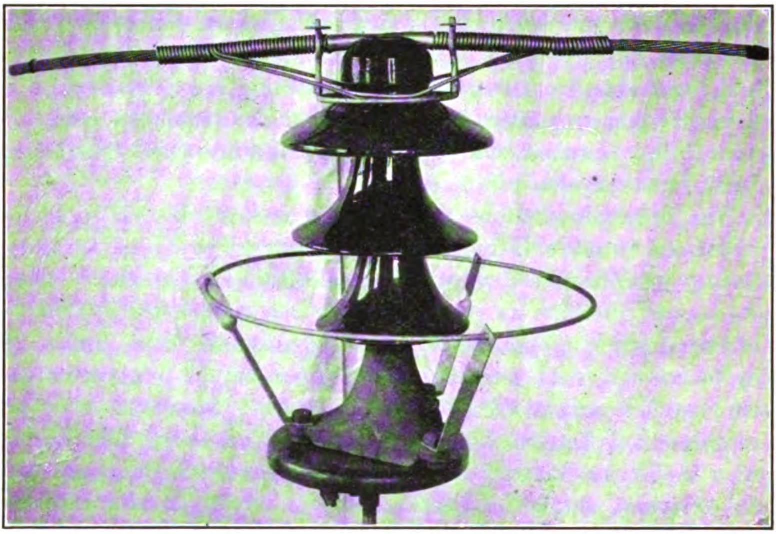

FIG. 7.—Arcing rings, to prevent injury to insulators by power effects

tive, on account of the tendency of the arc to flare upward and away from the porcelain. If, however, the very crater of the arc comes into actual contact with the porcelain, by reason of being located on the nether side of the tie-wire, or by reason of burning the tie-wire in two, which it may do if it remains at a single point, the headpiece of the insulator will be broken.

Considerable experimenting with high power arcs showed that the lower portion of the arc was averse to assuming anything like a horizontal position. It very much preferred not to make the bend about the base of the insulator to reach the pin. Thus, it was found that the lower arcing ring would take the arc im-

mediately after its formation to the pin, (which was accomplished by means of a fuse from tie-wire to pin, placed well up under the insulator parts) almost irrespective of the location of the ring with reference to the base of the insulator. On a quiet summer day, with practically no air movement to drive the arc away from the insulator, and naturally cause it to attack the ring, it was found that the arc instantaneously transferred from the pin to the lower ring, even though the ring was 20 in. larger in diameter than the base of the insulator, and as much as 4 in. below the base. The flaring nature and large size of these arcs, together with their tendency to assume an upright position afford the explanation of these results.

In the absence of wind it was apparent that the arc traveled rapidly from place to place around the insulator, and did not remain in any one place long enough to burn the tie-wire seriously. For this reason the headpiece of the insulator did not suffer, except perhaps to lose a little glaze. Under wind conditions, however, the arc hides behind the insulator on the leeward side and remains at or near one place on the tie-wire, sometimes burning it in two, and by coming into actual contact with the porcelain causes a breakage of the headpiece, but only the headpiece. The cure for this condition proved to be the use of a second ring about the head of the insulator, separated at all points from the porcelain. It was located just opposite the tie-wire, and of sufficient thickness fairly to resist serious burning.

Numerous tests were made, using as high as 30,000-kw. generator capacity, which under the short-circuit conditions of the test delivered 1200 amperes at an initial voltage of 60,000. In no instance was an insulator when equipped with both arcing rings damaged to the slightest extent. Fig. 8 is a night photograph of a 30,000-kw. arc. An insulator with arcing rings, in the midst of the fire, does not show. It was perfectly whole and fairly cool after this experience.

A typical case showing the manner in which insulators are destroyed by power arcs is shown in Fig. 13, which depicts an insulator destroyed in service by a power arc following a flashover by lightning.

The possible damage to the transmission cable by burning, in the event of the upper terminal of the arc traveling out along the cable, owing to wind blowing in the direction of the line, was fully dealt with experimentally, with and without arcing rings. It was found that a breeze of 3 miles per hour (estimated)

parallel to the line was sufficient to drive the arc out on the cable to a distance of 12 feet in four seconds. This was true whether the insulator was equipped with arcing rings or not. The amount of burning by three successive four-second applications of a 1200-ampere arc is shown by Fig. 9. It will be noted that the cable is not damaged materially at any one place, but that the scarring is distributed. This cable, which is 214,000 cir. mils aluminum, still retains 95 per cent of its original strength.

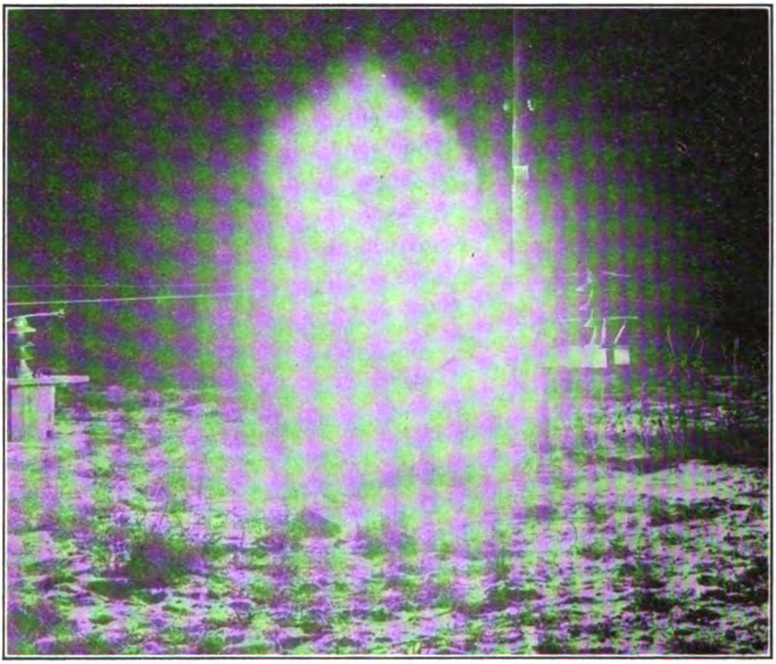

FIG. 8.—Night photograph of a 30,000-kw. 1200-ampere arc on an insulator equipped with arcing rings

As to what direction of wind, with reference to the line, will just cause the arc to go out on the cable, it is concluded from test results and observations on lines in service that with sloping ties such as are used on these lines it is necessary that the wind blow at an angle less than 30 degrees to the direction of the line. This value is not materially influenced by the presence of arcing rings.

Generally speaking, it is true that the transmission cables

are not more exposed to burning with arcing rings than without them, and in neither case is the burning at all serious. Fig. 10 shows a section of cable blistered in service by a short-circuit arc from a generating capacity of approximately 60,000 kw.

The arcing tests outlined above showed considerable latitude in the effective location of the lower ring. In addition, potential tests were made to determine the effect of this ring in various positions upon the flash-over voltage of insulators. It is evidently possible to set the ring high up on and close to the insulator, and thereby materially to decrease the effective insulation, since the initial discharge may pass to the ring, either from some point on the insulator or vertically downward from the cable, instead of passing over the entire insulator to the pin. The

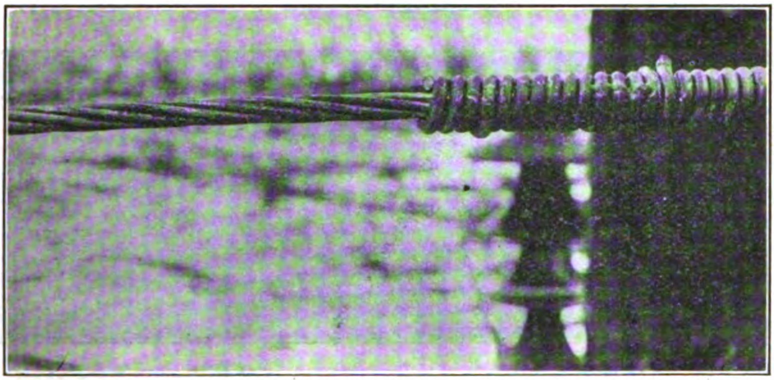

FIG. 9.—214,000 cir. mils aluminum cable burned by three applications of a 1200-ampere arc

extent of this influence not only depends upon the location of the ring, but in a fortunate way upon the condition of the insulator surface. Thus the dry flash-over value may be reduced as desired, to protect against voltages which are apt to puncture the insulator, while the normal minimum wet flash-over voltage need not be reduced. The insulator is thus left to develop its full flash-over value when most needed, and when least likely to result in puncture.

These effects appear graphically in Fig. 11. Curve *a* represents the ordinary performance of an insulator on a metal pin under spray, the flash-over voltage decreasing with the increase of water. Curve *b* shows its performance with the arcing ring so proportioned and so placed with reference to the insulator

parts as to effect a considerable reduction in the normal dry flash-over voltage, the initial discharge being to the ring instead of to the pin, without reducing the normal minimum wet flash-over voltage. Point *x* designates neutral conditions at which the initial discharge is as likely to strike to the ring as to the pin; at slower precipitation it strikes to the ring, and at higher rates to the pin. Of course, different insulators and different rings give different curves, but in any case it is possible to determine by experiment the size and setting of a ring necessary to accomplish definite results, within certain limits. Comparatively long insulators lend themselves best to such protection, and other things being equal, they need it most.

An important advantage arising from the use of a ring for this purpose, especially on long insulators of the type under con-

FIG. 10.—214,000 cir. mils aluminum cable burned in service by a short-circuit arc from six 10,000-kw. generators

sideration, is that the total reduction of voltage is effective on the lower part of the insulator, and relief is given where most needed. Thus it is well known that in an insulator of the pin type, the shell next the pin is subjected to more than its proportion of the total voltage acting. The potential gradient from the top of the grounded metal pin to the tie-wire in the insulator neck is believed to be such as to impose about 50 per cent of the total applied potential upon the pin-piece or inner shell of the insulator under consideration. At dry flash-over, therefore, the inner shell must resist a puncturing e.m.f. of something near 100,000 volts. This excessive potential on the inner shell may be reduced as much as desired by placing the lower arcing ring in proper proximity to the edge of the second or intermediate shell. A definite spark-gap is thus provided in parallel with the

lower part of the insulator, insuring the inner shell against puncture and, therefore, in all probability, the entire insulator.

Moreover, when a discharge of short duration occurs from, say the edge of the second shell to the lower ring, it is evident that the resistance of the surface of the insulator above the edge of the second shell is in series with such a discharge and has some deterrent effect upon the passage of the power-current. This

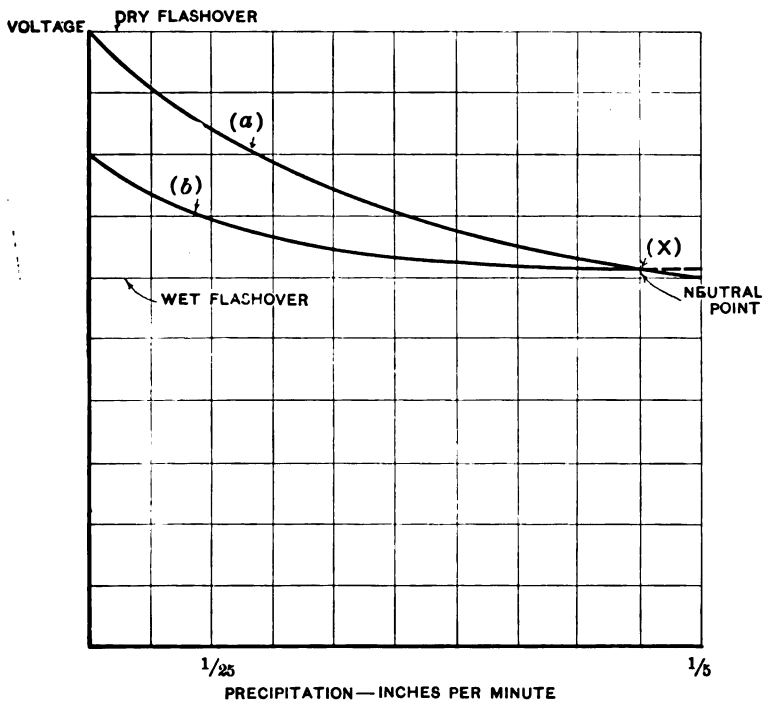

FIG. 11.—Flash-over characteristics of an insulator under spray, with and without arcing rings

(*a*) Without arcing rings

(*b*) With arcing rings adjusted to lower the " dry flash-over " without affecting minimum " wet flash-over "

is purely an operating advantage. Several cases have been discovered on the lines in service where such action has occurred. It is believed to be infrequent, however, since if an insulator flashes over by lightning, either partially or totally, the power-current is very apt to follow.

In addition to these considerations, the earth potential brought up around the insulator undoubtedly has an effect in ameliorating

the puncturing tendencies of high potentials, and provides more favorable electrostatic conditions at times of sudden shock. On this account it was thought that the long three-part insulator would suffer very much less than formerly from breakage of parts by lightning strains, and this has been fully substantiated by experience.

Before the summer or lightning season in 1909 a corrective programme as outlined below had been adopted and executed.

All the insulators on one of the duplicate lines and on some of the important branches, 195 miles in all (see Fig. 1) with more than 11,000 insulators, were removed from the line and subjected individually to a three-minute dry flash-over test of 195,000 volts from a 50-kw. 25-cycle testing transformer. Those which stood this test were returned to the line, and were installed on the two lower wires exclusively.

The results of this test are interesting and are shown in the following tabulation:

Total number of insulators tested (recorded)	10480
Total number failed by puncture of one or more parts	4172
Per cent failed	39.5

Individual parts failed as follows:

	Number of insulators failed	Per cent of number failed	Per cent of number tested
Headpiece only	504	12.1	4.8
Intermediate piece only	229	5.5	2.1
Pin-piece only	2317	55.5	22.1
Head and intermediate pieces	34	.8	.3
Head and pin-pieces	28	.7	.2
Intermediate and pin-pieces	830	19.9	7.9
All three parts	230	5.5	2.1

It is seen that 89.9 per cent of all failures involved the pin-piece, and that 55.5 per cent involved the pin-piece only.

It is only fair to say that these dry flash-over tests are very much in excess of any requirements which were anticipated at the time of the manufacture of these insulators. Had they been tested complete before their first installation, it would have been at a voltage certainly not in excess of 150,000, which is at present considered fairly high for a three-part 60,000-volt insulator. Prior to inaugurating flash-over tests on insulators from the line, some 2,000 insulatois in stock were tested to 150,000 volts,

3 minutes, resulting in a loss of 7 per cent, which cannot be considered excessive for an insulator of this shape.

On the top wire where most damage by lightning had occurred in the past, and on the lower wires to the extent necessary to accomplish their insulation, a new type of insulator, shown in Fig. 12, was installed. This is a four-part insulator of about the same outside diameter as the old style three-part insulator, but considerably shorter, 6 inches in fact. It flashes over dry at 190,000 volts, and wet at 105,000 volts. The individual parts and the assembled insulators were tested to dry flash-over voltage

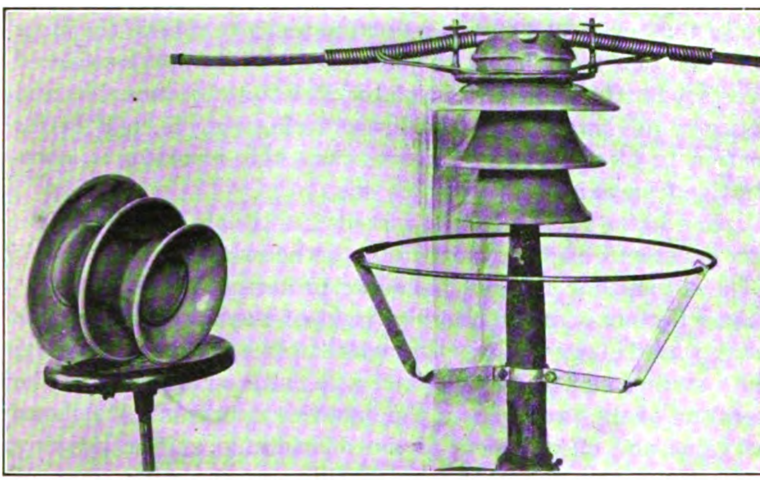

FIG. 12.—New style four-part insulator installed on top wire, 1909. Also shows method of attaching arcing-ring supports to cylindrical pins

for 3 minutes. There was a loss of 3 per cent of assembled insulators by this test.

An insulator of this design was selected in the light of experience, which clearly indicated that long insulator parts can ill resist the mechanical stress of lightning shocks, and that three thicknesses of porcelain are not sufficient safely to resist puncture in insulators having high flash-over characteristics. Moreover, short shells allow sufficient creepage at high voltage to effect a more nearly uniform distribution of potential upon the several parts, which prevents the puncture of any single shell by a disproportionate division of potential. In short, this four-part in-

sulator was designed to flash over rather than to puncture, and to do this with some margin of safety against puncture.

Lower arcing rings were installed on all insulators in such a manner that relief occurs at a maximum of 160,000 volts, and also in such a manner that wet flash-over values are not reduced. The maximum puncturing potential is thereby limited to approximately 30,000 volts less than the actual voltage which all insulators withstood under test, thus effecting a fair margin of safety against puncture. This result is accomplished by the use of a 26-in. by ⅜-in. iron ring, located approximately 2½ in. above the base of the three-part, and 2 in. below the base of the four-part insulators. It was thought that this relief was desirable for the three-part insulator, since practically the entire 30,000-volt reduction tends to relieve the inner shell, the one most liable to puncture. While not considered necessary for the four-part insulator it is not objectionable, and gives the advantage that the lower arcing ring is in a better location to attract the power arc, since this insulator is, comparatively speaking, a very short one.

Upper arcing rings were not installed until late in the season, after experience had shown them to be necessary.

The second line was not tested or protected in any way.

Since both lines are on the same right-of-way for a considerable distance, and in general pass through the same section of country, being at most a few miles apart, a definite comparison of the operation of the two lines for the lightning season of 1909 shows the value and effectiveness of the reinsulation and arcing ring protection. Also a comparison of these results with those of former years is of interest. It is to be remarked that the line selected for reinsulation is, when on a separate right-of-way, the southerly one, and apparently lies more in the usual path of electric storms than the one which was not reinsulated.

Table I is a comparison of lightning effects on reinsulated and non-reinsulated lines during 1909.

Item 1 shows that one insulator was disabled on the reinsulated lines against 54 disabled on the non-reinsulated lines. Fig. 13 pictures the one insulator lost on the reinsulated line. This is a clear case of breakage by power arc, after flashing over by lightning. It occurred early in the year, before inspection of the work has been made. This failure was due to improper installation of insulator and ring. The 54 insulators disabled on the non-reinsulated lines were destroyed in the same way as were those lost in former years, *viz.*, shattered by lightning, shattered by power arc and punctured.

TABLE I, SHOWING LIGHTNING EFFECTS ON REINSULATED AND NON-RE-INSULATED LINES, 1909

Reinsulated lines 195 miles, 11,078 insulators.
Non-reinsulated lines 217 miles, 15,121 insulators.
(Reinsulated lines are indicated in Fig. 1.)

Item	Reinsulated lines	Non-reinsulated lines
1. Insulators disabled	1 (a)	54
2. Insulators injured (replaced at convenience)	13 (b)	36
3. Occasions on which a line was disabled by breakage of one or more insulators	1 (a)	15 (c)
4. Short-circuits or grounds which tripped controlling circuit-breakers but did not disable the line	19	12 (c)
5. Number of days on which lightning was observed at one or more points on the system	44	44

(a) Broken by power arc. Insulator and rings were improperly installed.

(b) Nine injured in headpiece by power arc—no neck rings installed. One injured in lower skirts by power arc. Three injured in lower skirts by lightning stresses.

(c) Low, on account of practice of removing voltage from 110 miles of non-reinsulated line during lightning, to prevent breakage by power effects, and to obviate attending disturbances.

Item 2 shows that 13 insulators were injured on the reinsulated lines. A careful inspection of these lines was made after lightning storms to determine the exact performance of the arcing rings, and to learn whether or not their location was such as to give the desired results. The results of this inspection are as follows:

Total number of flash-overs found	38
Flashed but not injured	24
Headpiece injured (no upper ring installed)	9
Skirts injured by power arc	1
Skirts injured by lightning	3
Insulators disabled by power arc (improperly installed)	1
Arced to pin before transferring to ring (10, 4-part; 6, 3-part)	16
Arced to ring only 9, 4-part; 12, 3-part)	21
Arced to pin only (4-part insulator destroyed)	1

No insulator was punctured either totally or in any of its parts.

Fig. 14 shows an insulator, protected by a lower arcing ring, which flashed over successfully.

Fig. 15 pictures an insulator, the headpiece of which was broken by a power arc, burning the tie-wire in two. Eight

others were affected similarly. No upper arcing rings were installed on any of the insulators which were broken in this manner.

Fig. 16 shows the damage done by lightning stress to a three-part insulator. It had not flashed over. Three were injured in this manner.

Item 3 shows one occasion on the reinsulated line, and 15 on the non-reinsulated line, when the lines were disabled by the failure of one or more insulators. The single failure on the re-insulated line was due to the one insulator appearing in Item 1.

Fig. 13.—Four-part insulator destroyed by power arc. The only insulator disabled on the reinsulated lines 1909

Fig. 14.—Insulator, protected by lower arcing ring, which flashed over successfully

Item 4 shows momentary line interruptions caused by grounds or short-circuits, in which instances the lines were not disabled, but were all right for service at the next application of power, usually within thirty seconds. There were 19 of these interruptions on the reinsulated lines and 12 on the non-reinsulated lines. The fact that there were fewer on the non-reinsulated lines is believed to be due to the operating practice of removing voltage from more than a hundred miles of non-reinsulated line during the known progress of lightning storms in the vicinity of the lines. This was done to obviate damage by power arcs,

and to prevent attending disturbances to the system. It is interesting to note that this section of non-reinsulated line was disabled twice while no voltage was on it.

Considering Item 4 in conjunction with the results of line inspection mentioned above, it is evident that the lower arcing ring is not close enough to reduce the degree of insulation of the line under the average conditions of moisture during lightning storms. This is shown by the slight difference in the number of the momentary interruptions on the two lines, and by the fact that on the reinsulated lines in about half the instances

Fig. 15.—Insulator injured in head-piece by power arc. No upper arcing ring was installed

Fig. 16.—Insulator with second shell injured by lightning shock

the initial discharge was to the insulator pin, and in about half to the arcing ring. At the same time all puncturing of insulators has been eliminated. For these reasons it is believed that the rings have been placed so as to operate as originally intended.

Item 5 shows the number of days on which lightning was observed at one or more points on the system. This item is interesting in connection with Tables II and III.

Table II is a comparison of lightning effects on the reinsulated lines during 1909, and on the same lines previous to reinsulation during the years 1907 and 1908.

Table III is a comparison of the lightning effects on the non-reinsulated lines of 1909 and on the same lines in 1907 and 1908.

These tables are self explanatory. Attention is called to the extra severity of the lightning season of 1908, and to the fact

TABLE II. SHOWING LIGHTNING EFFECTS ON REINSULATED LINES DURING 1909, AND ON THE SAME LINES BEFORE REINSULATION DURING 1907 AND 1908

Item	1907	1908	1909
1. Insulators disabled	59 (*a*)	139 (*c*)	1
2. Insulators injured (serviceable)	16	35	13
3. Occasions on which a line was disabled by the breakage of one or more insulators	12	26 (*c*)	1
4. Short-circuits or grounds which tripped controlling circuit-breakers but did not disable the line	32 (*b*)	38 (*c*)	19
5. Number of days on which lightning was observed at one or more points on the system	41	54	44

(*a*) Low, on account of relief gaps.

(*b*) High, on account of relief gaps. This is one-half the total number on the entire system. In addition there were 100 grounds and short-circuits on the system which did not trip circuit breakers.

(*c*) High, on account of severity of season.

TABLE III. SHOWING LIGHTNING EFFECTS ON THE NON-REINSULATED LINES OF 1909, DURING 1907, 1908 AND 1909

Item	1907	1908	1909
1. Insulators disabled	29	81 (*b*)	54
2. Insulators injured (serviceable)	15	66	36
3. Occasions on which line was disabled by breakage of one or more insulators	9	23 (*b*)	15
4. Short-circuits or grounds which tripped controlling circuit-breakers but did not disable the line	32 (*a*)	42 (*b*)	12 (*c*)
5. Number of days on which lightning was observed at one or more points on the system	41	54	44

(*a*) High, on account of relief gaps. This is one-half total number of entire system. In addition there were 100 grounds or short-circuits on the system which did not trip circuit breakers.

(*b*) High, on account of severity of season.

(*c*) Low, on account of operating practice of removing voltage from 110 miles of line during lightning storms.

that the lines which were reinsulated in 1909 had formerly received rougher treatment than had the other lines.

From Table III it appears that lightning effects in 1909 were slightly more than half those in 1908, and somewhat in excess of those in 1907. It is therefore believed that the reinsulated

lines have been subjected to a lightning season of average intensity.

Concrete instances may be cited which show definitely that protected insulators have withstood severe lightning. In sections where the lines are 26 ft. apart on the same right-of-way, insulators were destroyed on the unprotected line in quantities, and in a manner which indicated extraordinary lightning severity. On the protected line in the same locality insulators flashed over uninjured. On six known occasions all the insulators

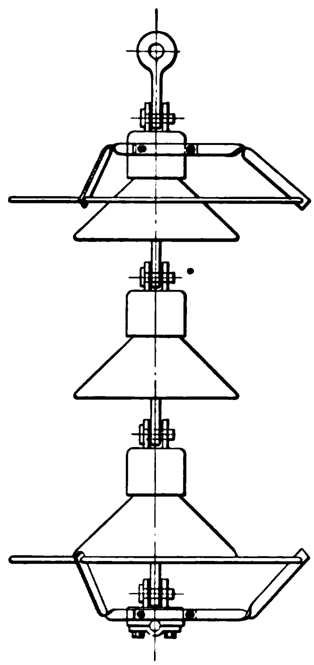

FIG. 17.—Arcing rings applied to a suspension type insulator

on a structure discharged, and on six other occasions two insulators per structure were involved. Of the 38 protected insulators which are known to have been affected, 21 were on the lower wires. These results are all indicative of severe lightning effects.

This experience with sound insulators protected by arcing rings justifies the feeling that extended interruptions due to line breakdowns by lightning will be very rare in the future, if they do not entirely disappear. Prevention of occasional momentary disturbances, caused by the discharge of one or more

conductors to ground from the effects of lightning, is believed to be impossible, since potentials exist at times which are too great to be insulated, and too severely localized to be relieved by lightning arresters at a distance. Duplication or multiplication of circuits controlled by proper automatic sectionalizing apparatus tends to prevent such interruptions from reaching the service.

Virtually no experience has been had with arcing rings on untested insulators. The work of applying them on the remainder of the system, omitting the testing of insulators, is in progress at present. In view of the material protection against puncture which the lower ring affords to the pin-piece of the three-part insulator, which piece, as the testing of 11,000 of these insulators shows, is the one most liable to puncture, and which if saved will probably result in saving the entire insulator, satisfactory results are anticipated.

Before undertaking the rather expensive experiment of reinsulating its lines and equipping them with arcing rings, the company sent representatives to various transmission plants in the United States and Canada to inquire about line troubles in general, and particularly regarding the effectiveness of overhead grounded conductors. The result of this investigation was not altogether favorable to the overhead ground wire. Various opinions were obtained expressing its usefulness and its uselessness. No plant comparable in extent and type of construction with the one under consideration was discovered which did not have to contend with the shattering and puncturing of insulators by lightning, as well as with occasional short-circuits during lightning storms. Considering the heavy expense of properly installing an overhead grounded conductor, and the extra load it would impose on the line structures, together with a large element of uncertainty as to its efficacy, the idea of installing one was abandoned.

While intentionally designed to protect insulators mounted on grounded metal pins it is believed that grounded rings would be beneficial to insulators on wooden pins also.

In view of the extensive use of suspension insulators, some experimental work has been carried on which indicates the necessity for, and effectiveness of, arcing ring protection on this type of insulator. The arrangement shown in Fig. 17 apparently accomplishes the desired results.

NOTE

The following paper will be read at the 246th meeting of the American Institute of Electrical Engineers in **Charlotte, N. C., March 30 to April 1, 1910.** All members of the Institute are invited to be present and participate in the discussion of the paper.

Written contributions will be read at the meeting, either in full, in abstract, or as a part of a general statement giving a summary of the views of the contributors.

The object of issuing the paper in advance of the meeting is to increase the interest and authority of the discussion by affording those desiring to participate, a longer time for the study of the paper and the preparation of their views.

Those desiring to contribute to the discussion at the meeting either orally or by letter, should notify **William S. Lee, Chairman Local Committee, Charlotte, N. C.,** not later than March 30, 1910. Written contributions arriving within 30 days thereafter will be treated as though presented at the meeting.

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

ON THE MODIFICATIONS IN HERING'S LAWS OF FURNACE ELECTRODES INTRODUCED BY INCLUDING VARIATIONS IN ELECTRIC AND THERMAL RESISTIVITY

BY A. E. KENNELLY

At the meeting of the American Electrochemical Society in October 1909, a paper was read by Mr. Carl Hering on "Laws of Electrode Losses in Electric Furnaces". At least seven interesting and important laws of electrode losses were enunciated and demonstrated in that paper, of which, however, only the two following need here be considered:

a. The combined loss through the cold end of an electrode is equivalent to the sum of the loss by heat conduction alone, (when there is no current) and half the $I^2 R$ loss.

b. This combined loss will be least when the loss by heat conduction alone is made equal to half the $I^2 R$ loss; the total loss will then be equal to the $I^2 R$ loss, and no heat will be conducted from the interior of the furnace.

In the discussion upon the paper the question was raised as to how far the temperature variation in electric and thermal resistivities of the electrodes modified these laws, since these resistivities might be considerably different at the hot and cold ends. This paper is devoted to a consideration of that question from an arithmetical point of view.

We will assume that both the electric and thermal resistivities are known at the hot end, as well as at the cold end of the electrode, from physical data for the electrode material at the furnace temperature and at the external air temperature. We will also assume that both resistivities change uniformly according to a straight-line law from the known value at the

cold end to the known value at the hot end. Thus, in Fig. 1, OX represents the length of an electrode, whose cold end O has a certain resistivity—either electric or thermal—represented by the ordinate OA, and whose hot end X has a corresponding resistivity represented to the same scale by the ordinate XB. We now assume that at any point P along the electrode, the resistivity considered has a value PQ, the point Q being found on the straight line AB. This assumption would be entirely justified if the resistivity followed the temperature according to a straight-line law, and also if the temperature increased uniformly along the electrode when at work. But in the working condition, the gradient of temperature is greater near the cold end than near the hot end. If only on this account, the actual resistivity curve probably deviates to one side or the other of the straight line AB. In assuming, therefore, straight-

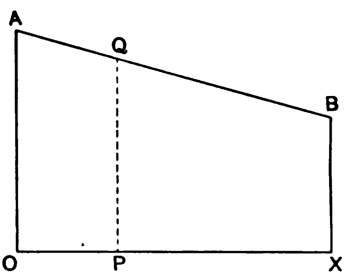

FIG. 1.—Diagram representing the assumed type of straight-line law in linear resistivities

line laws of resistivities from one end of the electrode to the other, we arrive at only a first approximation to the true solution of the problem, although we greatly simplify the solution. Nevertheless, the first-approximation solution which we shall develop is probably sufficiently close for ordinary practical purposes, especially as our data concerning the temperature variation of the resistivities is still very meagre. Moreover, since the results indicate that the first-approximation effect of the change in resistivities is relatively small, the necessity for seeking a second approximation becomes yet smaller.

In Fig. 2, OX represents a prismatic electrode with a length OX of X cm., and a uniform cross-sectional area of s cm², commencing at the cold end O, the temperature of which is taken as 0 degrees cent., and terminating at the hot end X, the temperature of which is taken as T degrees cent. The elec-

trode is assumed to be perfectly insulated at the sides, both electrically and thermally, by the surrounding furnace wall. If the temperature of the cold end should differ materially from 0 degrees cent. it suffices to reckon this temperature as 0 degrees and to deduct from the furnace temperature T a corresponding amount, so as to maintain the correct difference of temperature between the ends.

In the following demonstration C. G. S. units are employed throughout.

Let t_x = the temperature at any point of the electrode distant x cm. from O. (degrees cent.)

ϕ_x = The flow of heat through a cross-section of electrode distant x cm. from O, and reckoned as positive when in the direction $O\,X$ (abwatts).

I = the current strength passing through the electrode (absamperes).

$\rho_x = \rho_0\,(1 + a\,x)$ = the electric resistivity of the electrode at a point distant x cm. from O; where ρ_0 is the resistivity at the cold end, and $\rho_0\,(1 + a\,X)$ is the resistivity at the hot end (absohm-cm.).

$\sigma_x = \sigma_0\,(1 + b\,x)$ = the thermal resistivity of the electrode at a point distant x cm. from O; where σ_0 is the resistivity at the cold end, and $\sigma_0\,(1 + b\,X)$ is the resistivity at the hot end. (thermal absohm-cm.).*

The differential increase in heat flow occurring in the element dx is

$$d\phi_x = I^2\,\frac{\rho_x}{s}\,dx = I^2\,\frac{\rho_0}{s}\,(1 + a\,x)\,dx \qquad \text{abwatts (1)}$$

$$\therefore \frac{d\phi_x}{dx} = I^2\,\frac{\rho_0}{s}\,(1 + a\,x) \qquad \text{abwatts/cm. (2)}$$

* A unit cube of material of thermal resistivity σ absohm-cm. will permit a thermal flow of $1/\sigma$ abwatts, or ergs per second, when a difference of temperature of 1 degree cent. is maintained between a pair of opposite faces. The constants a and b may be either both positive, or both negative, or of opposite signs.

Also

$$\phi_x = -\frac{s}{\sigma_x} \cdot \frac{dt_s}{dx} = -\frac{s}{\sigma_0 (1+b\,x)} \cdot \frac{dt_x}{dx} \qquad \text{abwatts} \quad (3)$$

where the negative sign indicates that the flow of heat has a direction opposite to the positive direction of temperature gradient.

$$\therefore \frac{d\,t_x}{dx} = -\phi_x \frac{\sigma_0}{s} (1+b\,x) \qquad \text{degrees cent. per cm.} \quad (4)$$

Differentiating with respect to x, we have:

$$\frac{d^2\,t_x}{dx^2} = -\frac{d\phi_x}{dx} \cdot \frac{\sigma_0}{s} (1+b\,x) - \phi_x \frac{\sigma_0}{s} b$$

degrees cent. per cm. per cm. (5)

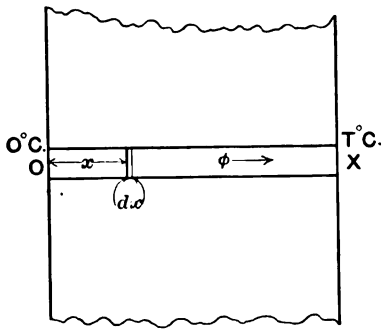

FIG. 2.—Electrode of uniform cross-section insulated both electrically and thermally in furnace wall

Substituting in (5) the value of $\frac{d\phi_x}{dx}$ in (2),

$$\frac{d^2 t_x}{dx^2} = -I^2 \frac{\rho_0\,\sigma_0}{s^2} (1 + ax + bx + abx^2) - \phi_x \frac{\sigma_0}{s} b$$

degrees cent. per cm. per cm. (6)

Differentiating again with respect to x,

$$\frac{d^3 t_x}{dx^3} = -I^2 \frac{\rho_0\,\sigma_0}{s^2} (a + b + 2abx) - I^2 \frac{\rho_0\,\sigma_0}{s^2} (b + abx)$$

degrees cent. per cm. per cm. per cm. (7)

$$= -I^2 \frac{\rho_0 \sigma_0}{s^2} (a + 2b + 3abx)$$

degrees cent. per cm. per cm. per cm. (8)

This is the fundamental differential equation connecting temperature with distance along the electrode. Integrating with respect to x, we have:

$$\frac{d^2 t_x}{dx^2} = -I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ (a + 2\,b)x + \frac{3ab}{2} x^2 \right\} + A$$

degrees cent. per cm. per cm. (9)

$$\frac{dt_x}{dx} = -I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ \left(\frac{a + 2\,b}{2} \right) x^2 + \frac{a\,b}{2} x^3 \right\} + Ax + B$$

degrees cent. per cm. (10)

$$t_x = -I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ \left(\frac{a + 2b}{6} \right) x^3 + \frac{a\,b}{8} x^4 \right\} + \frac{A}{2} x^2 + Bx$$

degrees cent. (11)

where A and B are integration constants to be determined from the terminal conditions. No new integration constant appears in (11) because $t_0 = 0$, by assumption.

In order to determine B, we may substitute X for x in (11), in which case $t_x = T$ degrees cent. This gives:

$$T = -I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ \left(\frac{a + 2\,b}{6} \right) X^3 + \frac{ab}{8} X^4 \right\} + \frac{A}{2} X^2 + BX$$

degrees cent. (12)

from which,

$$B = \frac{T}{X} - \frac{A}{2} X + I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ \left(\frac{a + 2b}{6} \right) X^2 + \frac{a\,b}{8} X^3 \right\}$$

degrees cent. per cm. (13)

substituting this value of B in (10), we obtain:

$$\frac{dt_x}{dx} = \frac{T}{X} - \frac{A}{2} (X - 2\,x) + I^2 \frac{\rho_0 \sigma_0}{s^2} \left\{ \left(\frac{a + 2b}{6} \right) (X^2 - 3x^2) \right.$$

$$\left. + \frac{ab}{8} (X^3 - 4\,x^3) \right\}$$

degrees cent. per cm. (14)

Using this result in (3), we have:

$$-\phi_x = \frac{1}{1+b\,x}\left[\frac{s}{\sigma_0}\cdot\frac{T}{X} - \frac{As}{2\sigma_0}(X-2\,x)\right.$$

$$\left. + I^2\,\frac{\rho_0}{s}\left\{\left(\frac{a+2\,b}{6}\right)(X^2-3\,x^2)+\frac{a\,b}{8}\,(X^3-4\,x^3)\right\}\right]$$

abwatts (15)

There remains the constant A to be determined from the known conditions of thermal flow. This constant A, which appears in (9) as a rate of change of temperature gradient, may be conveniently expressed as the sum of two parts, or

$$A = A_1 + A_2 \qquad \text{degrees cent. per cm. per cm.} \quad (16)$$

where A_1 depends only on the furnace heat-flow, or the flow of heat which would take place through the electrode in the absence of electric current, and A_2 depends only on the joulean heat-flow, or the flow of heat which would take place in the electrode with the electric current acting, but with no furnace heat, or a temperature 0 degrees cent. at both ends.

The total furnace flow will be obtained by dividing the difference of temperature, or thermomotive force, by the total thermal resistance of the electrode $\mathfrak{R}$, which is

$$\mathfrak{R} = \int_0^X \frac{\sigma_x}{s}\,dx = \frac{\sigma_0}{s}\int_0^X (1+b\,x)\,dx = \frac{\sigma_0}{s}\,X(1+b\,\frac{X}{2})$$

thermal absohms (17)

This means that the thermal resistance of the electrode, with a thermal resistivity varying in the manner assumed, is the same as that of an electrode having the same dimensions and a constant resistivity, equal to the arithmetical mean resistivity of the first. The furnace flow is thus:

$$-\phi_{x\,(I=0)} = \frac{Ts}{\sigma_0\,X\,(1+b\mathrm{v})} \qquad \text{abwatts (18)}$$

where $\mathrm{v} = X/2$

Putting $I = 0$ in (15) we obtain:

$$\frac{Ts}{\sigma_0 X(1+b\text{v})} = \frac{Ts}{\sigma_0 X(1+bx)} - \frac{A_1 s\,(\text{v}-x)}{\sigma_0\,(1+bx)} \quad \text{abwatts (19)}$$

from which

$$A_1 = \frac{T}{X}\left(\frac{b}{1+b\text{v}}\right) \quad \text{degrees cent. per cm. per cm. (20)}$$

The total joulean heat flow will be the integral of the $I^2 R$ loss in the electrode. The total electric resistance R is:

$$R = \int_0^X \frac{\rho_x}{s}\,dx = \frac{\rho_0}{s}\int_0^X (1+a\,x)\,dx = \frac{\rho_0}{s} X\left(1+a\frac{X}{2}\right)$$

absohms (21)

That is, the total resistance of the electrode with an electric resistivity varying in the manner assumed, is the same as that of an electrode having the same dimensions, and a constant resistivity equal to the arithmetical mean resistivity of the first. The total joulean flow is then, with $T = 0$:

$$-\phi_0 + \phi_X = I^2 \frac{\rho_0}{s} X\,(1+a\,\text{v}) \quad \text{abwatts (22)}$$

In (15), first put $T = 0$; $x = 0$; and then $T = 0$, $x = X$.

$$-\phi_0 = -A_2\frac{s\,\text{v}}{\sigma_0} + I^2\frac{\rho_0}{s}\left\{\left(\frac{a+2\,b}{6}\right)X^2 + \frac{a\,b}{8}X^3\right\}$$

abwatts (23)

$$\phi_X = -A_2\frac{s\,\text{v}}{\sigma_0\,(1+bX)} + \frac{I^2\rho_0}{s\,(1+bX)}\left\{\left(\frac{a+2\,b}{6}\right)2\,X^2 + \frac{3\,a\,b}{8}X^3\right\}$$

abwatts (24)

Adding (23) to (24) and equating to (22), we obtain:

$$A_2 = \frac{I^2\rho_0\sigma_0}{s^2\,(1+b\text{v})}\left\{\frac{bX^2\,(4a+8b+3abX)}{24} - 1\right\}$$

degrees cent. per cm. per cm. (25)

Substituting the above values for A and B in (11) and (15):

$$t_x = \frac{Tx}{X}\left(\frac{2+b\,x}{2+b\,X}\right) + I^2\frac{\rho_0\sigma_0 x}{s^2}\left[\left\{\left(\frac{a+2\,b}{6}\right)(X^2-x^2)+\frac{ab}{8}(X^3-x^3)\right\}\right.$$

$$\left. -\frac{X-x}{2\,(1+b\,\mathrm{v})}\left\{\frac{bX^2\,(4a+8b+3abX)}{24}-1\right\}\right]$$

degrees cent. (26)

and

$$-\phi_x = \frac{T}{X}\,\frac{s}{\sigma_0}\left(\frac{1}{1+b\mathrm{v}}\right)$$

$$+\frac{I^2\,\rho_0}{s\,(1+b\,x)}\left[\left\{\left(\frac{a+2\,b}{6}\right)(X^2-3\,x^2)+\frac{a\,b}{8}(X^3-4\,x^3)\right\}\right.$$

$$\left.-\left(\frac{\mathrm{v}-x}{1+b\mathrm{v}}\right)\left\{\frac{bX^2(4a+8b+3abX)}{24}-1\right\}\right] \qquad \text{abwatts (27)}$$

Consequently, substituting $x = X$ and $x = 0$ successively, we obtain after rearranging the terms:

$$-\phi_X = \frac{T}{X}\,\frac{s}{\sigma_0\,(1+b\,\mathrm{v})} - \frac{I^2\,\rho_0\,\mathrm{v}}{s\,(1+b\,\mathrm{v})}\left\{1+X\left(\frac{2\,a+b}{3}\right)+X^2\frac{a\,b}{4}\right\}$$

abwatts (28)

$$-\phi_0 = \frac{T}{X}\,\frac{s}{\sigma_0\,(1+b\,\mathrm{v})} + \frac{I^2\,\rho_0\,\mathrm{v}}{s\,(1+b\,\mathrm{v})}\left\{1+X\left(\frac{a+2\,b}{3}\right)+X^2\,\frac{a\,b}{4}\right\}$$

abwatts (29)

Equations (26) to (29) contain the complete solution of the problem under the assigned conditions. If we assume constant resistivities, or $a = b = 0$, they become:

$$t_x = T\,\frac{x}{X} + I^2\,\frac{\rho_0\,\sigma_0}{s^2}\,x\left(\frac{X-x}{2}\right) \qquad \text{degrees cent. (30)}$$

$$-\phi_x = \frac{T}{X}\cdot\frac{s}{\sigma_0} + I^2\,\frac{\rho_0}{s}\,(\mathrm{v}-x) \qquad \text{abwatts (31)}$$

$$-\phi_X = \frac{T}{X}\cdot\frac{s}{\sigma_0} - I^2\,\frac{\rho_0\,\mathrm{v}}{s} \qquad \text{abwatts (32)}$$

$$-\phi_0 = \frac{T}{X} \cdot \frac{s}{\sigma_0} + I^2 \frac{\rho_0 \text{v}}{s} \qquad \text{abwatts (33)}$$

which correspond completely to the formulas given in Mr. Hering's paper. That is, the total heat flow at the cold end is the sum of the furnace flow and half the joulean flow.

If we retain a in formulas (26) to (29), but put $b = 0$; *i e*, assume constant thermal resistivity, we obtain:

$$t_x = T \frac{x}{X} + I^2 \frac{\rho_0 \sigma_0}{s^2} x \left\{ \frac{a}{6} (X^2 - x^2) + \frac{X-x}{2} \right\} \qquad \text{degrees cent. (34)}$$

$$-\phi_x = \frac{T}{X} \frac{s}{\sigma_0} + I^2 \frac{\rho_0}{s} \left\{ \frac{a}{6} (X^2 - 3x^2) + (\text{v} - x) \right\} \qquad \text{abwatts(35)}$$

$$-\phi_X = \frac{T}{X} \frac{s}{\sigma_0} - I^2 \frac{\rho_0}{s} \text{v} \left(1 + \frac{2}{-} a X\right) \qquad \text{abwatts (36)}$$

$$-\phi_0 = \frac{T}{X} \frac{s}{\sigma_0} + I^2 \frac{\rho_0}{s} \text{v} \left(1 + \frac{a}{3} X\right) \qquad \text{abwatts (37)}$$

Similarly, if we retain b in formulas (26) to (29), but put $a = 0$; *i.e.*, assume constant electric resistivity, we obtain:

$$t_x = T \frac{x}{X} \left(\frac{2 + b x}{2 + b X}\right) + I^2 \frac{\rho_0 \sigma_0}{s^2} x \left\{ \frac{b}{3} (X^2 - x^2) \right.$$

$$\left. - \frac{X - x}{2 (1 + b \text{v})} \left(\frac{b^2}{3} X^2 - 1\right) \right\} \qquad \text{degrees cent. (38)}$$

$$-\phi_x = \frac{T}{X} \frac{s}{\sigma_0} \left(\frac{1}{1 + b \text{v}}\right) + I^2 \frac{\rho_0}{s (1 + b x)} \left\{ \frac{b}{3} (X^2 - 3x^2) \right.$$

$$\left. - \left(\frac{\text{v} - x}{1 + b \text{v}}\right) \left(\frac{b^2}{3} X^2 - 1\right) \right\} \qquad \text{abwatts (39)}$$

$$-\phi_X = \frac{T}{X} \frac{s}{\sigma_0 (1 + b \text{v})} - \frac{I^2 \rho_0 \text{v}}{s (1 + b \text{v})} \left(1 + X \frac{b}{3}\right) \qquad \text{abwatts (40)}$$

$$-\phi_0 = \frac{T}{X} \frac{s}{\sigma_0 (1 + b \text{v})} + \frac{I^2 \rho_0 \text{v}}{s (1 + b \text{v})} \left(1 + X \frac{2b}{3}\right) \qquad \text{abwatts (41)}$$

Formulas (36) and (37) show that with the electric resistivity alone varying, the joulean heat does not divide equally between the two ends of the electrode. The part escaping through the furnace end is such as would be produced in an electrode of uniform resistivity equal to that actually found at distance $X/3$ cm. from X; while the part escaping through the external end is such as would be produced in an electrode of uniform resistivity equal to that actually found at distance $X/3$ cm. from O. With a essentially negative in carbon, the joulean flow through the furnace end would be less than that through the external end.

Formulas (28) and (29) may also be obtained in a different way, as follows: Referring to Fig. 2, the joulean power developed in the element $d\,x$ is defined by equation (1). This power divides into two current elements, one $d\phi_x$ escaping through the furnace end, and the other $-d\phi_0$, escaping through the outer end. This division may be expressed:

$$d\phi = -d\phi_0 + d\phi_{\mathrm{x}} \qquad \text{abwatts (42)}$$

The division is effected in inverse proportion to the thermal resistances on each side of the element dx. The thermal resistance $\mathcal{R}_0$ between O and x is:

$$\mathcal{R}_0 = \frac{\sigma_0}{s}\, x \left(1 + \frac{b}{2}\, x\right) \qquad \text{thermal absohms (43)}$$

The thermal resistance $\mathcal{R}_{\mathrm{x}}$, between x and X is:

$$\mathcal{R}_{\mathrm{x}} = \frac{\sigma_0}{s} \left\{ (X - x) + \frac{b}{2}\, (X^2 - x^2) \right\} \qquad \text{thermal absohms (44)}$$

The total thermal resistance $\mathcal{R} = \mathcal{R}_0 + \mathcal{R}_{\mathrm{x}}$ from O to X is expressed by (17). The divisional currents are therefore:

$$-d\phi_0 = d\phi\, \frac{\mathcal{R}_{\mathrm{x}}}{\mathcal{R}} = d\phi\, \frac{(X - x) + \frac{b}{2}\,(X^2 - x^2)}{X\,(1 + b\,v)} \qquad \text{abwatts (45)}$$

$$= \frac{I^2\rho_0(1 + ax) \left\{ (X - x) + \frac{b}{2}\,(X^2 - x^2) \right\} dx}{sX\,(1 + b\,v)} \qquad \text{abwatts (46)}$$

$$d\phi_x = d\phi \frac{\mathcal{R}_0}{\mathcal{R}} = d\phi \frac{x\left(1+\frac{b}{2}x\right)}{X\,(1+b\,\mathrm{v})} \qquad \text{abwatts (47)}$$

$$= \frac{I^2\rho_0(1+ax)\left\{x\left(1+\frac{b}{2}\,x\right)\right\}dx}{sX\,(1+b\mathrm{v})} \qquad \text{abwatts (48)}$$

Integrating (46) and (48) from $x = 0$ to $x = X$, we find the total currents $-\phi_0$ and ϕ_x, as expressed in (28) and (29) respectively, after taking the furnace flow into account as in (18).

Numerical Example No. 1, with Constant Thermal Resistivity, or $b = 0$

We may take as an example a graphite electrode of length $X = 50$ cms. and of uniform cross-section $s = 100$ sq. cm., terminating in a furnace with a temperature elevation of $T = 1600$ degrees cent. Let us first assume that both the electric and thermal resistivities of this electrode are uniform throughout its length ($a = b = 0$). We may take the electric resistivity as $\rho = 0.85 \times 10^6$ absohm-cm.* (0.00085 ohm across a block 1 cm. cube, or 0.000333 ohm across a block 1 inch cube), and the thermal resistivity as $\sigma = 2.5 \times 10^{-7}$ thermal absohm-cms. (1 degree cent. across a block 1 cm. cube would transmit $1/(2.5 \times 10^{-7})$ abwatts of thermal flow, *i e.*, 1/2.5 watts; or $1/(2.5 \times 4.19)$ gm. calories per sec.)

The steady current strength which will be consistent with the minimum waste of heat in this electrode will be, by (33) $I = 245.6$ absamperes (2456 amperes), representing a current density of 24.56 amperes per sq. cm. The electric resistance of the electrode will be 0.425×10^6 absohms (0.425×10^{-3} ohm), the drop of potential in the electrode 1.044×10^8 abvolts (1.044 volts) and the joulean power expended $I^2 R = 2.560 \times 10^{10}$ abwatts (2560 watts).

The thermal conditions of the electrode are represented in Fig. 3, where abscissas along $O X$ represent distances, and ordinates the temperature to the right-hand scale in degrees cent. The thermal current strength is indicated in watts to the left-hand scale. The straight line $O T$ indicates the temperature at different points along the electrode, in the steady state, when

* The thermal and electric resistivities used in this example are borrowed from Mr. Hering's October paper.

no electric current flows, but the furnace temperature is independently maintained. The parabola OPX indicates the temperature which would be reached, in the steady state, at each point of the electrode, if the furnace were cold but full

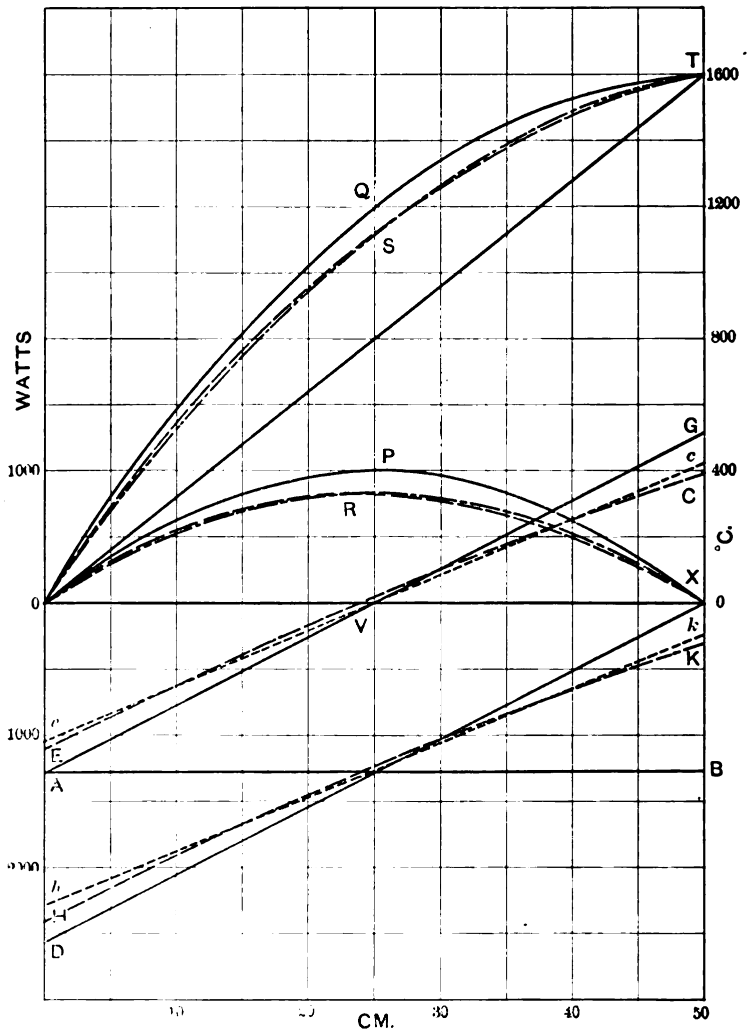

FIG. 3.—Thermal chart for electrode of uniform thermal resistivity

electric current were maintained. Thus, the middle point P of the electrode would attain a temperature elevation of 399.5 degrees cent.; while the two extremities O and X would have no temperature elevation.

Under working conditions the above two thermal states would be superposed, and the temperature at each point of the electrode is shown by the curve $O\ Q\ T$, which is the parabola $O\ P\ X$ superposed on the straight line $O\ T$.

Again, the furnace temperature elevation of 1600 degrees cent. working through the thermal resistance of the electrode (1.25×10^{-7} thermal absohms), would determine a thermal current flow of $1600/1.25 \times 10^{-7} = 1.28 \times 10^{10}$ abwatts or 1280 watts, which is constant at all points along the electrode, as indicated by the horizontal straight line $A\ B$. Again with the furnace cold, and the electrode active, there would be no thermal current at the middle point V; but there would be a positive, or furnace-directed thermal current at all points between V and X, together with a negative, or outwardly-directed, thermal current at all points between O and V. This condition is represented by the straight line $A\ V\ G$, with 1280 thermal watts escaping from each end. In the working condition, the above thermal currents are superposed and the total current is represented by the straight line $D\ X$, with no current in either direction at the furnace end, but with 2560 thermal watts leaving the outer end O. All this is in accordance with the principles enunciated in Mr. Hering's paper.

Let us next assume that at the furnace end, owing to the influence of the temperature elevation of 1600 degrees cent., the electric resistivity of the graphite electrode is only 64 per cent of its value at the outer end; or $\rho_X = 0.544 \times 10^6$ absohm-cm., also that the resistivity falls uniformly from O to X as expressed by the relation $a = -0.0072$, or $\rho_x = 0.85 \times 10^6\ (1 - 0.0072\,x)$ absohm-cm. Then if the thermal resistivity remains constant, ($b = 0$) we find by formula (34) that the furnace temperature gradient $O\ T$ Fig. 3 remains unchanged; but the curve of joulean temperature gradient $O\ R\ X$ is no longer a parabola, but a cubic, which reaches its maximum (330 degrees) at R, about 23 cm. from O, the two sides $O\ R$ and $X\ R$ being dissymmetrical. The total temperature gradient in the working state is the broken line $O\ S\ T$, and is the sum of the broken line $O\ R\ X$ and the straight line $O\ T$.

Again, the furnace thermal current through the electrode is shown at $A\ B$, 1280 watts as before; but the joulean current is the broken line $E\ C$, with 973 watts flowing out of the furnace end, and 1127 watts from the outer end. The total thermal current in the working state is indicated by the broken curved

line $H K$, with 307 watts escaping from the furnace, and 2407 watts escaping at the outer end.

If instead of using the correction formulas (34) and (35), we assume a constant electric resistivity at the mean value between ρ_0 and ρ_x, or $\rho = 0.697 \times 10^6$ absohm-cm. ($a = b = 0$), then the furnace gradient $O T$ remains unchanged; but the joulean gradient becomes a new parabola, represented by the dotted line $O R X$, reaching its maximum of 328.7 degrees cent. at the middle point V of the electrode. The total temperature gradient is then the dotted line $O S T$, which differs only very slightly from the broken line $O S T$ of the correction formula. Again, the joulean thermal current is indicated by the dotted straight line $e c$, intersecting $O X$ in V. The flow out of each end of the electrode is 1050 watts. The total thermal current in the working state is indicated by the straight line $h k$ with 230 watts escaping from the furnace, and 2330 watts from the outer end.

It is evident that with the electrode dimensions, the range of temperature elevation, and the resistivity here assumed, the corrected formula only changes the thermal current by 77 watts at each end.

Numerical Example No. 2, with Both Resistivities Variable

We may next consider a case in which both the electric and thermal resistivities vary. This is represented in Fig. 4. The electrode dimensions, furnace temperature elevation, and electric current strength, are all taken as in the preceding case; but we assume $\rho_x = 0.85 \times 10^6 \, (1 - 0.0072 \, x)$ absohm-cm. and $\sigma_x = 2.5 \times 10^{-7} \, (1 + 0.01 \, x)$ thermal absohm-cm., which make at the furnace end the electric resistivity 36 per cent less, and the thermal resistivity 50 per cent greater, than their respective values at the outer end O. Computing the distribution of temperature and thermal current by the correction-formulas (26) and (27) we obtain the broken lines of Fig. 4. The furnace gradient is $O U T$, no longer a straight line, the drop of thermal potential (temperature) being greater toward the furnace end where the resistivity is greater. The joulean gradient is the broken curve $O R X$, which, being a cubic, is not symmetrical, and which reaches a maximum of 405 degrees cent. about 26 cm. from O. The total gradient in the working state is shown at $O S T$.

The furnace thermal current $A B$, Fig. 4, is 1025 watts, uniform at all points, and directed towards O. The joulean thermal

current is indicated by the broken curved line $E\,c$, that leaving the furnace at X being 910 watts, and that leaving the outer end O being 1206 watts. The total thermal current is given by

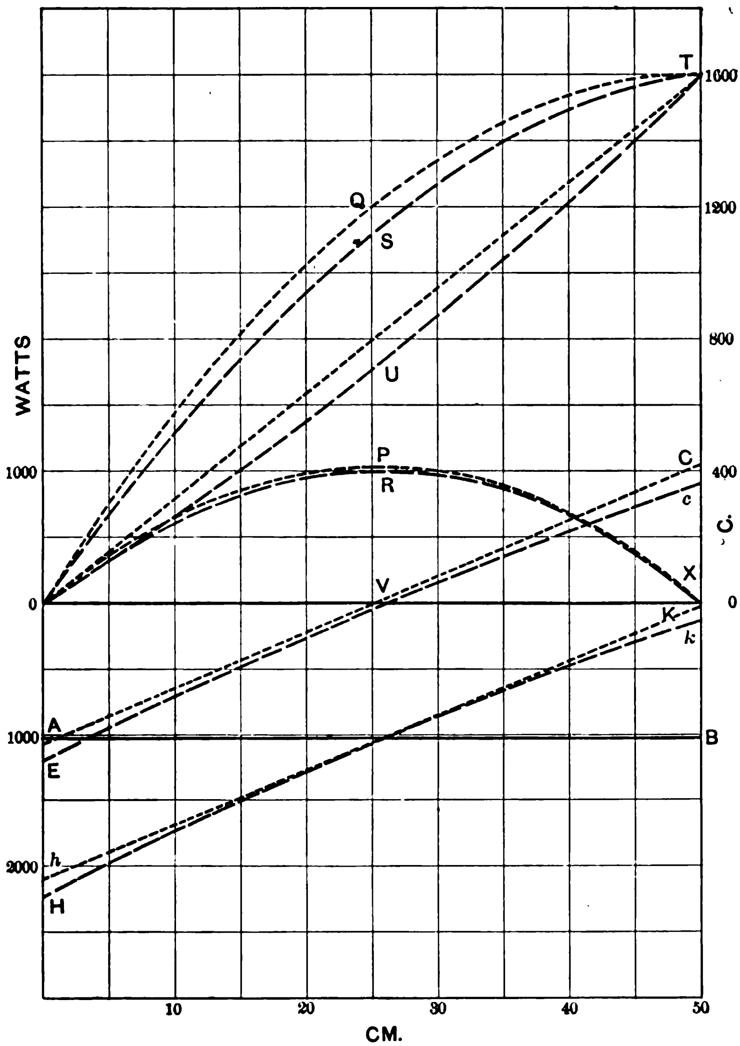

FIG. 4.—Thermal chart for electrode having variation in both electrical and thermal resistivities

the broken line $H\,k$, 115 watts leaving the furnace at X, and 2231 watts leaving the outer end at 0.

If instead of using the correction formulas, we take the simple

formulas (30) and (31) of constant resistivities, and the arithmetical mean of each, we have $a = b = 0$, $\rho = 0.697 \times 10^6$ absohm-cm., $\sigma = 3.125 \times 10^{-7}$ thermal absohm-cm. We then obtain the dotted lines of Fig. 4. The furnace gradient becomes the straight line $O\,T$. The joulean gradient is the parabola $O\,P\,X$ with its maximum of 411.0 degrees cent. The total gradient in the working state is $O\,Q\,T$.

The furnace thermal current $A\,B$ is uniform at 1025 watts, as in the corrected case. The joulean thermal current is the straight line $A\,C$, with 1050 watts escaping from each end. The total thermal current in the working state is the dotted straight line $h\,K$, with 25 watts leaving the furnace at X, and 2075 watts leaving the open end at O.

The errors due to taking mean resistivities are therefore, in this case, 140 watts at the furnace end, and 156 watts at the outer end. The magnitude of this error tends, in general, to increase with the length of the electrode, the electric current density, the magnitudes of the resistivities, their range of variation, and the furnace temperature elevation. Considering the present imperfection of our knowledge concerning electrode resistivities, it will ordinarily not be worth while to take the extra time necessary for working out the correction-formulas. In most cases the mean resistivities, as used in Mr. Hering's paper, will give satisfactory results.

If we examine formula (29) and consider what cross-section of electrode will minimize the total escape of heat from the outer end, we differentiate (29) with respect to s, and equate to zero in the usual way. This requires that the first term of (29); *i e.*, the furnace flow, shall be equal to the second compound term, or joulean flow. Consequently, in the general case when both resistivities vary, the minimum heat-waste is found when the joulean flow through the external end is equal to the furnace flow. This is the same relation as was stated in Mr. Hering's paper. Whereas, however, the joulean flow through the outer end was pointed out in that paper to be half the total joulean flow with constant resistivities, it is not, in general, half the joulean flow when either one or both of the resistivities can vary.

Within the assumptions to which the above inquiry has been confined, Mr. Hering's first two laws may be amended as follows, to meet the conditions of variable thermal and electrical resistivity.

a. The combined loss through the cold end of an electrode is

equivalent to the sum of the loss by heat conduction alone (when there is no current) and approximately half the $I^2 R$ loss, the exact fraction depending on the temperature coefficients of the resistivities. With constant resistivities, the fraction will be one-half.

b. The above combined loss will be least when the loss by heat conduction alone is equal to the joulean loss through the cold end. The total loss will then be approximately equal to the total joulean loss and very little heat will flow into or out of the furnace. With constant resistivities, this resultant furnace flow will be nil.

List of Symbols Employed

a = the distance coefficient of electric resistivity (1/cm.).

b = the distance coefficient of thermal resistivity (1/cm.).

$A = A_1 + A_2$, an integration constant (degrees cent. per cm. per cm.).

B = an integration constant (degrees cent. per cm.).

I = current strength through electrode (absamperes).

ϕ_x = thermal current in direction OX, through a cross section of the electrode, at distance x cm. from the outer end (abwatts).

$\mathcal{R} = \mathcal{R}_0 + \mathcal{R}_x$ = thermal resistance of the electrode (thermal absohms).

R = electric resistance of the electrode (absohms).

ρ = electric resistivity (absohm-cm.).

σ = thermal resistivity (thermal absohm-cm.).

ρ_x = electric resistivity at distance x cm. from outer end (absohm-cm.).

σ_x = thermal resistivity at distance x cm. from outer end (thermal absohm-cm.).

s = cross-sectional area of electrode (sq. cm.).

T = temperature-elevation of furnace over outer end (degrees cent.).

t_x = temperature-elevation of any point on the electrode x cm. from and above the outer end. (degrees cent.).

v = $X/2$ (cm.).

x = distance from outer end to a point on the electrode (cm.).

X = length of the electrode (cm.).

NOTE

The following paper will be read at the 246th meeting of the American Institute of Electrical Engineers in **Charlotte, N. C., March 30 to April 1, 1910.** All members of the Institute are invited to be present and participate in the discussion of the paper.

Written contributions will be read at the meeting, either in full, in abstract, or as a part of a general statement giving a summary of the views of the contributors.

The object of issuing the paper in advance of the meeting is to increase the interest and authority of the discussion by affording those desiring to participate, a longer time for the study of the paper and the preparation of their views.

Those desiring to contribute to the discussion at the meeting either orally or by letter, should notify **William S. Lee, Chairman Local Committee, Charlotte, N. C.,** not later than March 30, 1910. Written contributions arriving within 30 days thereafter will be treated as though presented at the meeting.

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

(Subject to final revision for the Transactions.)

THE PROPORTIONING OF ELECTRODES FOR FURNACES

BY CARL HERING

Introductory. The usual rules for proportioning electrodes for electric furnaces have been based on such factors as allowable current densities, least practicable resistance (hence shortness and large section), lowest heat conduction, the summation of losses due to the electric resistance and to the heat conduction to get the total, etc.

Believing that these laws were not based on correct principles, and were therefore unsatisfactory and perhaps even misleading, and as apparently no one had made a thorough investigation of this subject based on unquestioned fundamental laws, the writer some time ago made a careful study of the true principles underlying the proper proportioning of electrodes, based on indisputable physical laws. The results of this analysis showed that our former rules were not only entirely inadequate, but were even quite incorrect and led us into entirely wrong conclusions. And as the value of the annual loss of energy in such electrodes is very large, the matter of the correct proportioning is of considerable commercial importance as well as of interest to the engineer. This analytical investigation was then supplemented with an experimental one in which the necessary physical constants and the behavior of different electrode materials were determined.

The purpose of the present paper is to give a general review of these investigations from the standpoint of the engineer who is concerned with the proper design and operation of furnaces, and to discuss more particularly the practical bearing of the results of the experimental part, including the proper propor-

tioning of the electrodes, the selection of the best material, the calculation of the losses, the indications of the faults in existing constructions and their remedies, etc.

Some parts of these investigations have been published or are being published elsewhere, to which those interested are referred. The present paper will include only a general summary of these and will discuss more particularly the experimentally determined data not included in the other papers.

Fundamental principles. The fundamental principle of the present analysis of the electrode problem, is that the heat gradient at the hot end should be zero; that is, the line representing it should be horizontal at that end. This means that no heat will then traverse through the hot end, either one way or the other; hence no heat from the furnace or its products is lost through the electrode, and the product can therefore not be "chilled" by the electrode as has often been found to be the case with improperly proportioned electrodes. Such an electrode would act as a perfect heat insulator, better even than the walls of the furnace.

This zero gradient can be obtained only by having the temperature of the hot end of the electrode equal to that of the furnace. In the present method this is done by so proportioning the electrode that the current through it will raise the temperature of the hot end to this furnace temperature.

Although the writer's first recommendation of this fundamental principle was met with scepticism and even ridicule, it is now believed to be generally accepted as the correct one. One's first impression, that this would consume much energy, is found to be incorrect; the explanation is briefly, that as the heat near the hot end has no easy means of escape, (for as it cannot get into the furnace it must all flow out at the cold terminal) it will rapidly accumulate, so that a small amount of energy will soon produce a high temperature. Under simplifying assumptions, (and perhaps under all conditions) this state of temperature equilibrium, is found to be also the condition of minimum total loss of energy in the electrode.

Although this way of operating an electrode is quite the contrary to that dictated by prior practice, which was based on the lowest practicable resistance, it turns out to be the most economical, even though it may involve an intentional increase of the resistance loss; it is the total loss which should be considered, as the watts of heat lost either from the furnace or in the electrodes cost the same.

Another advantage is that the whole interior of the furnace then becomes useful, because a furnace in which there was a chilling action around the electrodes, by a mere change of proportions of the electrodes, based on this principle, can then have its capacity increased to that of its full interior size.

It furthermore means that all the heat escaping at the cold end is then the $I^2 R$ heat. Or inversely, if all the heat escaping at the cold end is the total $I^2 R$ heat, and neither more or less, then the temperature of the inner end will be that of the furnace, and there will be no loss of furnace heat and therefore no chilling.

It is evident that this condition can be reached regardless of how good or bad a heat conductor the electrode material is; even with such a very good heat conductor as copper. Hence, even without any further analysis, this shows the fallacy of the oft repeated and generally accepted statement that a good heat conducting electrode material necessarily chills the furnace, and is therefore objectionable. It will at once be seen that electrodes of good heat conducting materials must simply be made smaller in section than others.

Besides this fundamental principle there are a number of other features in which the writer's conclusions differ very radically from our former practice. The second one is in the determination of the total loss of energy in an electrode. According to the usual former practice, as shown in even very recent papers, the total loss was assumed to be the sum of that due to heat conduction alone and that generated in the electrode itself by the current. The writer found that this also was a fallacy and was not founded on a correct analysis. The true total is the sum of the conduction heat and only half the $I^2 R$ heat, under the simplest condition of constant conductivities and no loss of heat to the walls. This has since been confirmed by others also and is now, it seems, generally accepted. Under the more complicated conditions of varying conductivities, it is claimed by some to be only approximately true, but in any case it is much more nearly correct than the older method.

It is easily seen why it should be so. The heat conducted from the furnace when there is no current, flows over the whole length of the electrode, hence the drop of temperature is proportional to the total flow; but the $I^2 R$ heat is generated throughout the whole length, hence is equivalent to the whole of it entering at the middle and flowing over only half the length, or to half of it flowing over the whole length. Hence as far as

the drop of temperature between the ends is concerned, only half of that corresponding to the $I^2 R$ heat must be added to that due to conduction alone.

A third point of difference, and one which is still adhered to tenaciously by some, concerns the current density. This was formerly the basis of electrode design and is still considered so by some writers. The present investigation, however, has shown this to be a fallacy also. It has shown that the current density does not enter as a fundamental factor which determines the proportions. Even more than that; to base the proportions on current densities may even mislead one into using entirely incorrect proportions with unnecessarily large electrodes and losses of energy, accompanied by a false assurance that it is the best that can be done. It may have been found that when certain current densities were exceeded, troubles arose, but in the writer's opinion the mistake made was in attributing them to the current densities instead of to the length; it can be shown that the same current density will cause the electrode to become too hot or too cold, depending upon the length of the electrode. And conversely, for a given length a fixed current density prescribed by rule of thumb may be either much too high or much too low. Current density cannot therefore be a determining factor; it is no more a factor in the proportioning of electrodes than it is in calculating transmission lines, and should be abandoned the same as it was in the latter case years ago.

Since the writer pointed this out, a crude attempt has been made to defend the older practice by claiming rather vaguely that in some way the current density should be modified with the length. This is " beating around the bush " and would be an unnecessarily awkward and roundabout method, even if definite rules which are directly applicable had been given by the defender of that method, which was not the case.

The writer's conclusions are that current densities need not be considered at all as a determining factor, not any more so, and perhaps even less so, than in the calculation of transmission lines. He has operated electrodes very successfully and with the greatest possible economy of power at heretofore unheard-of current densities; and he knows of cases in which far lower current densities were concluded (erroneously) by furnace engineers to have been too high.

The fourth point of difference in the present method is in the resistance. The writer has found that the usual rule, to make

it as low as practicable, is a mistake. It can be shown that the resistance for the most economical operation is not at all a matter of choice. It is determined by the conditions of the problem and is fixed by the temperature, current and material; it is different for different materials; hence to try to make the resistances the same for different materials is improper designing.

This investigation, of course, applies to the electrode proper, or what might be termed the essential electrode, or the chief part of an electrode, namely the part which passes through the walls, and in which the coöperation of the two heat flows is the governing feature. Any additional parts within the furnace or projecting beyond the outside of the walls, are not theoretically essential parts even though they may be very necessary in practice; such parts are evidently determined by entirely different conditions and considerations and must be treated apart from that portion which is absolutely necessary to lead the current from the outside to the inside of the furnace. To attempt to combine the various parts of such a longer electrode and to treat them as one in an analysis for finding out the laws governing the proportions, would either be impossible or would at least lead to endless complications rather than to a simplification.

Hence throughout the present paper the proportions of the electrode and particularly the length, refer to this essential part passing through the wall; the prolongations at either or both ends, if any, (as for instance the part embraced by the metallic terminal, or the extra part allowed for feeding) must be determined separately, being governed by entirely different considerations. When the metallic terminal surrounding the outside end is close against the wall and relatively short as compared with the part within the walls, it would probably be sufficient for most practical purposes to consider the electrode proper as ending at the middle of this terminal. And unless the cooling water is very close to the electrode, and the heat resistance between the electrode and cooling water is very low, the temperature at the virtual end of the essential part of the electrode will be higher, and perhaps considerably higher, than the cooling water, hence the drop of temperature in the electrode proper will be less; it will be shown below that the hotter the outside terminal, the smaller the loss in the electrode.

This shows the fifth point of difference from our former views. Instead of trying to keep the outside terminals as cool as practicable, we ought to try so to design them as to let them get as

hot as practicable, even to the extent of heating them with a blast lamp, when such heat is cheaper than electric heat. This will economize power, provided of course that the electric heat comes from the electrode proper and not from a poor terminal contact. The section of the electrode, however, becomes larger by raising the outside temperature.

A sixth point of difference from former practice which is brought out by this analysis is that instead of tending to make electrodes large, we should on the contrary try to make them small, as they can then be just as efficient; and there may even be other advantages also, besides economy of material, terminals, etc., in doing so.

Another complete departure from former methods is in the abandoning of the conductivities of the materials as factors in calculating electrodes and electrode losses. The writer found that the desirable qualities of electrodes do not depend on either the electric or the thermal conductivity alone, but on certain relations between the two. The analysis shows that our former deep-rooted conviction that a high heat conductivity is a bad feature for an electrode, is entirely wrong. The fact is, that it may be a good or a bad quality, depending upon the electrical conductivity. Neither alone is a criterion or a measure of excellence, and to consider them so misleads us.

In the writer's method of designing electrodes both qualities have been abandoned entirely as a basis of proportioning, and they have been replaced by two new qualities which are true and correct measures of excellence of those materials when they are used for electrode purposes; moreover they greatly simplify the calculations. Apparently the only objection to them is that they are not yet found in that form in tables of physical properties; they are however easily calculated from the conductivities, if the latter are known. That they are new and unfamiliar quantities will, it is believed, not be considered an objection by those who will take the time to understand their meaning.

These two new measures of electrode qualities are the "electrode voltage" and the "specific cross-section", these specific names having been given them in order to distinguish them clearly from other quantities. They are both measures of physical properties, quite as much so as conductivities, specific heats, specific gravities, etc., and are constants for the particular materials; that is, they are independent of

the dimensions. The former concerns the power loss and the latter the size. The lower their values are the better is the material for electrodes. They will be further discussed below.

Analytical

In an analytical investigation to determine the theoretical relations or laws in a complicated case involving many variable factors, especially in an entirely new field, the writer has followed, and is entirely in accord with, the teachings of such able authorities as Thomson (Lord Kelvin) and Taite, and doubtless of others also; namely, that it is best to solve such a problem first under the simplest possible conditions or premises, as a first approximation, and afterward to consider the refinements (if necessary) as a second or even third approximation. An attempt at the start to solve the complete problem with all its numerous less important refinements, as advocated by some of the writer's critics, would be more likely to obscure and lead us away from those simple and instructive approximate relations, which are often so valuable to the constructing engineer, than to lead us toward them and to point them out to us. A minor factor which might be absolutely negligible in practical calculations may give rise to very great complications in strictly correct algebraic expressions of a desired relation, thereby completely obscuring the more useful approximate one.

Hence in the present investigation, after a number of trials, it was found best first to eliminate all but the main or essential factors by limiting the premises to the simplest conditions. This made it possible to determine the fundamental relations or laws of electrodes, which prove to be very interesting and useful. By proceeding in this way, it was found that most, and perhaps all, of the more important corrections due to the minor factors, like the variations of the conductivities with temperature, could be combined into two experimentally determined coefficients or constants, and by the use of these in the original formulas, all the important, and perhaps even also the unimportant corrections can readily be included. A method was then devised by the writer for determining these constants experimentally, and was carried out by him; the results will be given below. This combination method is believed to be a simpler and more practical way of solving the complete problem with all its intricacies, than the purely analytical one, which even if it were completed, could not be used in practice until certain extended

experimental determinations had been made, as no one has yet made them. As the present method of using the simplest possible formulas and embodying all the correction factors in two experimentally determined constants, seems to be not only simple but even more accurate and reliable than the other more complicated method would be, it is believed that the necessity for the other solution and for the long series of experimental determinations, which it is based upon, no longer exists.

The premises of the present simplified analysis are: that the cross-section is uniform; that the two conductivities have the same values over the whole length; that the electrode is heat insulated except at its ends; also that the Thomson effect, the skin effect, and other similar minor factors are neglected. Under these premises the following relations are rigid and exact, and may therefore be called the laws of electrode losses.

Laws of electrode losses:

a. The combined loss through the cold end of an electrode is equivalent to the sum of the loss by heat conduction alone (when there is no current) and half the $I^2 R$ loss.

b. This combined loss will be least when the loss by heat conduction alone is made equal to half the $I^2 R$ loss; the total loss will then be equal to the $I^2 R$ loss, and no heat will be conducted from the interior of the furnace.

c. This minimum loss is dependent only on the material, current and temperature, but not on the absolute dimensions; it merely fixes the relation of the cross-section to the length, but leaves a choice of either; hence

d. For economy of electrode material the length should be made as short as practical considerations permit.

e. For each material there is a definite minimum loss of electrode voltage which depends only on the temperature and is independent of the dimensions or the normal current for which the furnace is designed; hence

f. The best possible electrode efficiency for any material may be determined from the total voltage of the furnace and this minimum voltage due to the material and the temperature, and is independent of the dimensions.

g. The temperatures indicated by the heat gradient of the combined flow are equal to the sums of those of the individual flows.

The proof of these laws is given in a paper by the writer on

" Laws of Electrode Losses in Electric Furnaces ",* and need not be repeated here.

The starting point is the fundamental principle, first announced by the writer a year ago as the proper one, namely, that no heat should leave or enter the furnace through the electrode or in other words, that the heat generated by the electrical resistance shall raise the temperature of the hot end to that of the furnace; it is shown that under the given conditions this is also the condition of least total loss.

Watts, a measure of flow of heat. Before giving the formulas, the writer desires to explain that it is quite correct, and it simplifies such calculations greatly, to represent and measure a flow of heat in terms of the electric unit watts, instead of in calories per second. A watt is just as correct a measure of a flow or current of heat (calories per second), as an ampere is for measuring a flow of electric current in coulombs per second. Heat is energy, and a rate of flow of heat per second is power, hence it is measurable in units of power like watts. Since the writer called attention to this, others have endeavored to improve matters by calling this unit " watt seconds per second ", but this cumbersome name is entirely unnecessary and obscures rather than simplifies our conceptions. It is evident that watts $\times$ seconds $\div$ seconds = watts. When the heat conductivity of a material is given as 10 watts for an inch cube, it simply means that with one degree cent. difference of temperature between two parallel sides, and perfect heat insulation on the other four, the same amount of energy will flow through as heat, say into water at the cold end, as would enter the water from a coil of resistance wire in which 10 watts were being set free.

In the following, therefore, all flows of heat will be represented in watts, and it is recommended that in future all thermal constants pertaining to electrodes be given in terms of watts instead of calories per second. The conversion factors are: gram calories per second $\times$ 4.18617 = watts, and watts$\times$0.238882 = gram calories per second.

Formulas. The following formulas are the same whether inches or centimetres are used, provided they are employed consistently throughout, including all those constants which are based on dimensions, and which of course will be different; those like the electrode voltage or watts per ampere are, of course, the same in both systems. All the formulas in this paper are in

*Trans. Amer. Electrochem. Soc. Vol. 16, p. 265.

terms of actual units and may therefore be used directly in practice.

Let S = cross-section in square inches;
L = length in inches (the essential length);
I = current in amperes;
W = watts generated electrically in the electrode;
H = heat flow in watts which would flow if there were no current.
h = heat flow in watts which enters the hot end from the furnace;
X = heat flow in watts leaving the cold end;
T = temperature drop in centigrade degrees between the hot and cold ends;
r = electrical resistivity in ohm, inch cube units;
k = thermal conductivity in watt, inch cube units;
e = electrode voltage in volts;
E = total voltage between the two ends, or the watts per ampere;
s = specific cross-section in square inches;
S' = section in square inches per ampere per inch of length (or in sq. cm. per ampere per cm. length if the other quantities are in terms of centimetres).

In general, the flow of heat in watts at the cold end is

$$X = H + W \div 2 \tag{1}$$

and entering at the hot end

$$h = H - W \div 2 \tag{2}$$

in which

$$H = k\,T\,S \div L \tag{3}$$

and

$$W = r\,I^2\,L \div S \tag{4}$$

The total flow out of the cold end will be a minimum when

$$H = W \div 2$$

Representing this minimum flow by $m X$, then

$$m X = 2 H = W = I \sqrt{2 k r T} = I e \sqrt{T} \tag{5}$$

this it will be seen does not contain either S or L, which means that this is the same for all dimensions; it includes the condition however that the ratio of the section to the length is

$$S \div L = I \sqrt{r \div 2 k T} \tag{6}$$

which means that either the length or the section may be made anything one desires, provided only that the ratio is equal to the above. As the length is usually fixed by other conditions this formula is best written

$$S = I L \sqrt{r \div 2 k T} \tag{7}$$

The electrode voltage is

$$e = \sqrt{2 k r} \tag{8}$$

and the total voltage is

$$E = \sqrt{2 k r T} = e \sqrt{T} \tag{9}$$

both of which are seen to be independent of the dimensions or the current, the electrode voltage being even independent of everything except the properties of the material, and hence itself a physical constant. This means that for every material there is a fixed and definite voltage for one degree which voltage is the same no matter what the size of the electrode or the normal current, provided only that it is correctly proportioned so that no heat flows through the hot end.

Conversely, the total voltage E being known, a convenient way is at hand of finding out whether the hot-end temperature of the electrode is that of the furnace or not, as this voltage might be measured without much difficulty during the operation of the furnace; if the measured voltage is found to be less, the electrode is chilling the furnace, if greater, the electrode is getting hotter within the wall than it is in the furnace.

The electrode voltage is that physical constant which is a true

measure of the loss of power in an electrode. When multiplied by the square root of the temperature drop and by the current, as shown in (5), it gives the minimum loss in watts which can possibly be obtained with that material, for that current and temperature. Hence if its value is known, it is not necessary to know the two conductivities in order to calculate this loss of power.

The quantity E is measured directly in the experimental determinations described later; hence it is known for each temperature and material. Substituting its value (9) in equation (5) gives

$$m\,X = I\,E \tag{10}$$

That is, the minimum loss in watts may be determined directly by multiplying this value of E by the current; hence the voltage E may be called the " watts per ampere ".

This shows the simplified method suggested by the writer, for calculating these minimum losses. It consists in tabulating for each material the values of E for different temperatures, as obtained directly by experiment (by the method described below); then for any given case, in which of course the current and temperature are given, one needs merely to multiply the corresponding value of E by this current to get the result. This is so simple that it can often be done mentally. The values of the conductivities need therefore not be known.

Returning to formula (7), if I, L and T are made unity, that is, for 1 ampere, 1 in. length and 1 degree cent. of temperature, the resulting cross-section, now represented by s, becomes

$$s = \sqrt{r \div 2\,k} \tag{11}$$

This the writer proposes to call the " specific section ", because it is a physical property of the material, as its value, like that of the electrode voltage, depends only on the relations of other physical properties. It is a true measure of the size of an electrode, of course always under the condition that the electrode operates as was specified. This quantity therefore is the mate to the electrode voltage and determines the size just as the latter determines the loss.

Now let S' be another quantity so that

$$S' = s \div \sqrt{T} = \sqrt{r \div 2\,k\,T} \tag{12}$$

It will then be seen that in the same way and for the same purpose as was described above for E as compared with e, it is possible to determine by direct measurement (by the method described below) the values of this quantity S' for various temperatures and for each material. When these values are tabulated it again becomes an extremely simple matter to calculate the proper cross-section, because

$$S = I\,L\,S' \tag{13}$$

that is, one needs merely to multiply this value of S' from the tables by the current and the length to get the actual cross-section. This quantity S' is therefore here termed the " section per ampere per inch of length ". Hence this calculation is also reduced to a surprisingly simple one, provided these tabulated values are at hand. Such a set of values of both S' and E is given below in Table II.

When S' is not known, then

$$S = I\,L\,s\sqrt{T} \tag{14}$$

It will be seen that again the two conductivities drop out and need therefore not be known. In the absence of these tables the values of e and s should be used. If they too are unknown the mean conductivities must be resorted to. If in turn these electrode means are not known and the conductivities at the specified temperature are known, the mean values must first be determined from them. If these conductivities vary greatly with the temperature, a closer approximation could be obtained by taking into consideration the mutual effects of these variations on each other and on the mean, as described later in the discussion of the experimental results.

In this connection the writer desires again to call attention to the fact on which particular stress was laid in his first published description of his method, and which fact has been entirely ignored by the critics, that the curve of the combined losses is quite flat at its minimum point. This means that a considerable error can be made in the cross-section without affecting the power loss appreciably; for instance in a certain case an error of 10 to 20 per cent in the cross-section near the minimum point produced an error of only 1 to 3 per cent in the loss. Hence great accuracy in determining the values of these conductivities is

not required for engineering purposes, even though to the physicist these slight variations produce great complications in the algebraic analysis. The degree of complication produced by a factor in a rigid mathematical analysis is no measure of its real importance.

Another reason why great accuracy in the values of these conductivities is not necessary for engineering purposes is that they both occur under the square root sign in the formulas used for electrodes (5) and (6); hence if one of them, as for instance the thermal conductivity which is the one least best known, is four times too great, the result will be only twice too great.

Various other relations exist between these old and new quantities which at times are of interest and use. They are easily deduced and are therefore merely summarized here.

$$e = I \div W\sqrt{T} \tag{15}$$

$$e = r \div s \tag{16}$$

$$s = e \div 2\,k \tag{17}$$

Mean values and equivalent electrodes. All the above is based on the premise that the temperature variations of the physical constants may be neglected; this so greatly simplifies the formulas and relations that the numerous useful and interesting results given above, are obtained. They would certainly not have been brought to light from the extremely complicated relations which result when the temperature variations are introduced algebraically. This is the reason why the writer prefers the method of studying a new problem by means of simplified assumptions first, leaving the corrections due to small variations to be introduced afterward as a second or third approximation, if indeed such accuracy is necessary in calculations of furnaces which unlike dynamos, transformers and other electrical apparatus, cannot possibly be built or operated under very exact specifications. Hence great accuracy in the present investigation is merely of academic rather than of engineering interest.

In the complete form of the method as described by the writer in the original paper on this subject and repeated here, the variations of the conductivities are taken care of very effectively and no doubt more effectively than by intricate calculations,

by determining the constants under the very same conditions under which they are to be used. This point was also overlooked by the critics. It embodies the desired correction factors in the constants themselves, hence they need no further attention. Even if the values at specific temperatures are known, which is not the case for carbon and graphite, the writer doubts very much whether the final results calculated from them by means of the more accurate and decidedly more complicated algebraic relations, would prove to be as close to the actual as they are when determined by the present extremely simple method.

In the present method the values of the conductivities and other deduced factors obtained as will be described, are the means peculiar to electrode conditions. What they really represent are the values of another or *equivalent electrode* the conductivities and other properties of which are the same as these mean values, and are constant from end to end, that is, they are independent of the different temperatures along the electrode.

Such an equivalent electrode will as a whole operate in exactly the same way, and hence, as far as the flows of heat at the two ends are concerned, it is theoretically identical. It differs however in the shape of that part of the temperature gradient which is intermediate between these two end points. Hence, whenever this intermediate heat gradient is concerned and only then, one must consider the nature of the temperature variations. This will be shown below in the discussion of the experimental results.

A brief summary of the discussion which has taken place concerning this and other features of the writer's method, will be given at the end of this paper

Experimental

Most engineering calculations of structural work are based on the physical properties of materials often called " constants " even though their values vary somewhat; the proper designing of electrodes is no exception. When not done in this way it becomes a process of more or less skillful guessing which ought not to be called engineering. Until these constants are determined, calculations based on them of course cannot be made. At the time when the present investigation was begun some of the necessary physical properties were either not known at all, or known only very vaguely and indefinitely; this refers chiefly

to the heat conductivities. No particular need for them had existed, but since it had become possible to calculate electrodes on a rational basis, the need of these constants was felt. The writer therefore undertook a determination of them for graphite, carbon, iron and copper. The tests were made in the well equipped Electrical Testing Laboratories in New York City.

The method used was the one suggested in his recent paper on " A New Method of Measuring Mean Thermal and Electrical Conductivities of Furnace Electrodes."* It is based on the same fundamental principles and formulas as those of this analysis. Briefly it consists in effect in operating a pair of electrodes under conditions approximating as nearly as possible those under which they should (according to this analysis) be operated in practice, namely that the electrodes shall not chill the furnace; or more scientifically speaking, that the heat gradient at the furnace end shall be zero, represented by a horizontal temperature line, in which case there will be no flow of heat into or out of the furnace through the hot end of the electrode.

While thus operating, the current, voltage and cold temperatures are carefully measured for various furnace temperatures. The heat flow is by this method measured electrically in terms of watts before it is heat, thereby avoiding the necessarily cumbersome and often inaccurate measurements of flows of heat in the form of heat. From the data obtained the mean thermal and electrical conductivities or resistivities and several even more important constants are calculated by the formulas given, which are practically the same as those in which they are afterwards used to calculate other electrodes. Further details are given in the above mentioned paper.

The method therefore amounts to measuring the constants of an electrode under actual operating conditions, and when these conditions are what they should be in practice. Hence it is very direct and does not involve any questionable process of determining the constants under one set of conditions and applying them to entirely different ones. The only important difference between the conditions of the test and those of the subsequent application of the constants, is in the dimensions of the electrodes. These constants are specific quantities; that is they are reduced to values per inch or centimetre units, hence they should apply equally well to large or small electrodes, if minor effects, such as the differences in the ratio of the surface to the volume, are

*Trans. Amer. Electrochem. Soc. Vol. 16, p. 317.

neglected. If further proof of this is necessary, it has been furnished by Dr. E. F. Northrup, who in an unpublished article has demonstrated that even under the complex conditions of the operation of electrodes, it is strictly correct to apply the constants obtained by this method to electrodes of different lengths or cross sections or both, provided that the temperature conditions at the ends are the same, and that the heat insulation is also relatively the same.

The constants given by this test are the *mean* values for the electrode *as a whole* and when operating under the proper conditions. The conductivities thus obtained are not necessarily the arithmetic means of those at the ends or even the averages taken at equally spaced distances. They are means peculiar to operating electrodes, and their relations to the end values or to the mean of the values at equally spaced distances, are different for different materials. For this reason the writer has proposed the term " electrode mean " to designate them. They are the correct mean values to be used in the formulas determined by the present analysis, and as it would be difficult to calculate them accurately from values like those given in the usual tables, for different specified temperatures (if such values existed for electrode materials which they apparently do not), they are best determined experimentally by a direct method like the one described, if indeed it is not also an easier and more reliable method than those formerly used; it gives the proper mean values directly, while the other methods do not. While great accuracy in these constants is seldom if ever necessary in practice for calculating electrodes, it is desirable, to use them in an investigation like the present, in which comparisons and other deductions are to be made and in which the behavior of electrodes is to be studied.

The reasons why these mean values are peculiar to electrodes, will be best seen below in the discussion of the experimental results.

This phase of the subject is discussed more in detail in an article to be published elsewhere. It will suffice to say here that these means depend upon the distribution of the heat in the electrodes; that is, on the temperature curve. This is different for different materials and depends on the joint coöperation of both the electric and the thermal conductivities, because each affects the other. These means are in fact the values of an equivalent electrode which as a whole would operate exactly

like the original one, as explained above. Hence in the present method these differences in the temperature curves are eliminated as far as the action of the electrode as a whole is concerned; they need be considered only in connection with the relations between the electrode and the surrounding furnace wall.

The details of the determination of these constants are described in a paper to be read before the American Electrochemical Society at its Spring meeting. The purpose here is to compare and discuss the results, and to endeavor to point out what they teach us. It will be sufficient to say here that the tests were made with care; the results, as far as they go, are believed to be reliable and even more accurate than is required for most practical purposes. Sets of measurements were made for each of several temperatures for each material, and the final result of each run is an average of a number of very closely agreeing sets of readings. The furnace temperatures were kept constant for periods of about 10 to 30 min. to within about 1 per cent and generally considerably less, it being an important feature of this test to reach the stable state of temperature.

The iron and copper electrodes were run to as near their melting points as practicable. The iron had unfortunately been injured slightly by an accidental excessive temperature prior to the last test, near its melting point, hence the values at the highest temperature are not as closely accurate and reliable as the others, but they are probably not far wrong. The same was the case with the highest temperature values for graphite. Allowances for these have been made in the curves. Less care was taken with the lower temperature values as they were of less importance.

Above about 900 degrees cent. the graphite and carbon electrodes began to be affected presumably by the gases in the granular insulating material, (magnesite), probably by the CO from the incompletely calcined carbonate. The results beyond that point were therefore thrown out, and those near it may not be quite correct.

The full lines in the accompanying curve sheets represent the ranges over which the results were actually measured; the dotted lines are exterpolated and therefore are only probable values. These exterpolated values were added here with some hesitancy as the writer is well aware of the possible danger in relying on the extensions of formulas and curves beyond the actual measured ranges. In the present case however the several curves for each

material are linked by fixed relations, hence it is not like simply prolonging individual curves; an incorrect extension of one curve will be likely to show on the others, and perhaps in an exaggerated form. For this reason the extension of each one aids in determining the extensions of some of the others. They are therefore probably more nearly correct than mere unguided and independent extensions would be; in fact it seems likely that these fixed relations are far better guides for these extensions than the curvatures of the known parts of individual curves.

In all these curves the exterpolated values were checked at 2000 degrees cent. and 1400 degrees cent. by these relations, and whatever differences were found were distributed over the curves where they corresponded best with the curvatures of the known parts. A second approximation was thus obtained and this was again adjusted, and so on until a final agreement was reached. This care was taken because at present there exist no reliable data concerning these mean values for those temperatures, and it was thought that the exterpolated values were at least better than none at all, as they were not likely to be far wrong. They are offered here merely for what they are worth and nothing more. The tests for determining these constants become tedious for the higher temperatures on account of the oxidation or other forms of deterioration of the carbon and graphite, and the melting of the metals. It may therefore be some time before the tests are repeated for those temperatures. Until then these exterpolated values may perhaps be of some service. Attention may here again be called to the fact pointed out above, that the curve of minimum loss is rather flat at the minimum point, hence quite a large error in the correct proportions will give rise to only a small one in the energy loss; close accuracy in the constants is therefore not necessary.

There may, of course, be radical changes in these physical constants at the melting points of the metals, and at some points at which carbon may change its condition. These cannot be predicted. The present extensions are all based on a regular continuation of the measured relations.

Although all the electrodes were very nearly $\frac{5}{8}$ ins. in diameter they differed slightly, hence for comparing them more correctly with each other, the results have here all been reduced to a diameter exactly of $\frac{5}{8}$ in. For the same reason they have also all been reduced to a constant cold terminal temperature of

100 degrees cent. by adding or subtracting the required amount to both temperatures. The error involved in doing this is no doubt absolutely negligible for the present purposes. The data were obtained from electrodes 8 in. long measured between the furnace end and the furnace side of the water-cooled terminal.

When the method described in this paper is used for calculating electrodes, the important physical constants in these determinations are the electrode voltage and the specific section described above, and others related to them (E and S'). The two conductivities are then eliminated as separate quantities and need not be considered. They have nevertheless been included in the following curve sheets as matters of interest and of use in studying the subject. The original measured data, namely the current and volts have also been added, after reducing the former as described; they lead to interesting and valuable deductions.

As the current densities in some of these runs were extraordinarily high, it may be of interest to add here that the electrodes behaved very well, so well in fact that the writer would not hesitate to use such extreme current densities in regular practice under the proper conditions. The results prove his contention, which has been disputed by others that the current density is absolutely no factor in the determination of the proportions of electrodes. As the curves for the values of the current densities would be exactly like those for the current, they have not been repeated on the curve-sheets.

Experimental data. The experimental results and the deductions calculated from the data are given in the accompanying Table I which explains itself; the exterpolated data are given in italics so as to distinguish them from the others.

In order to compare and study these data more readily, they have been plotted in Figs 1 to 11. In Figs. 1 to 4 the properties are compared for each of the materials, while in Figs. 5 to 9 the materials are compared under each of the properties. In Figs. 10 and 11 the two most important of these properties are compared; they were omitted from the other sheets for the sake of clearness.

In all the curves the scales give their actual values and not merely relative ones; hence as these scales are very different for the different materials, it is not proper to compare with each other the curves of the same property for the different materials without making due allowance for the different scales; they may be compared directly only as far as percentage differences are

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Length

Material
Carbon...
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Graphite...
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Iron......
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Copper....
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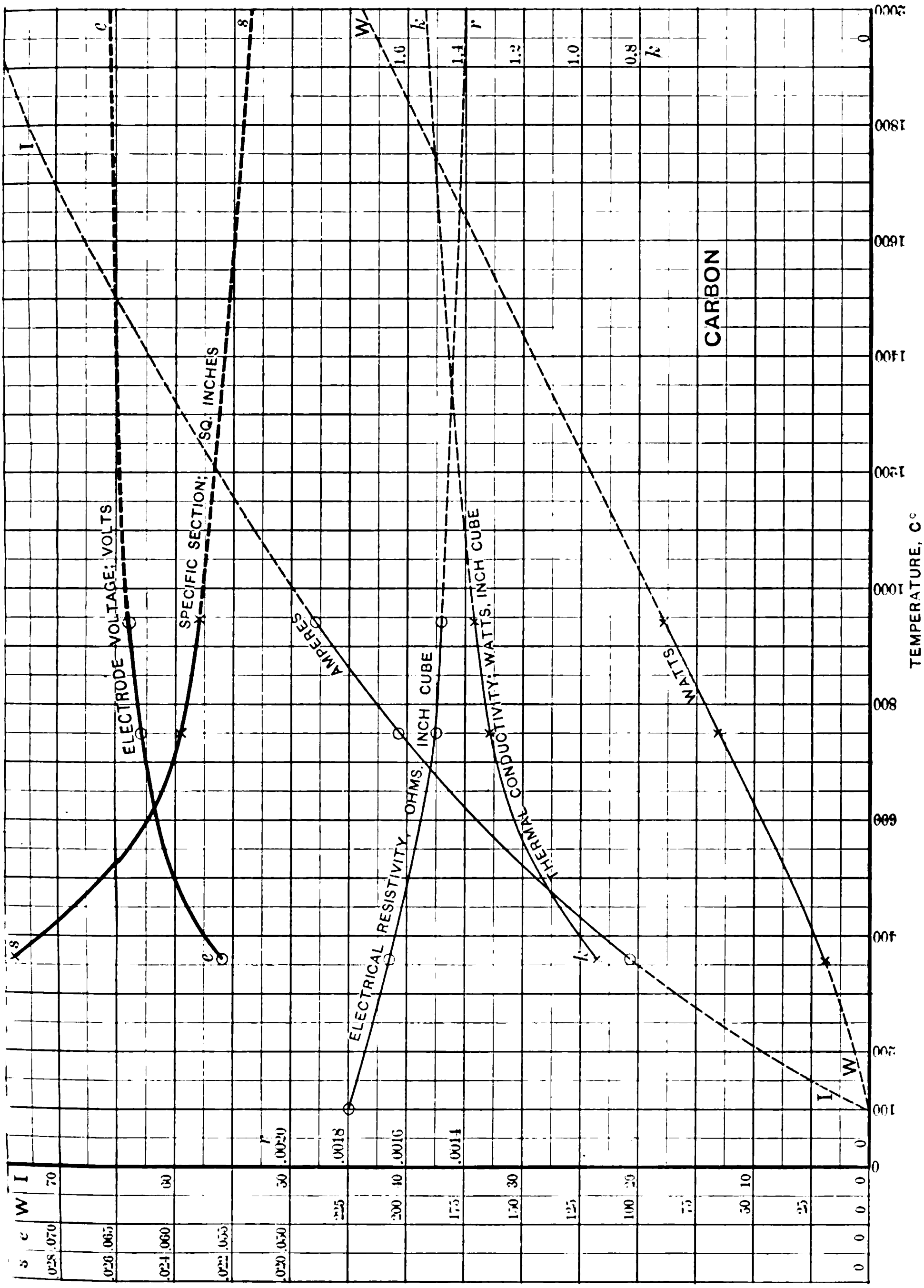


FIG. 1.—Electrode properties of carbon

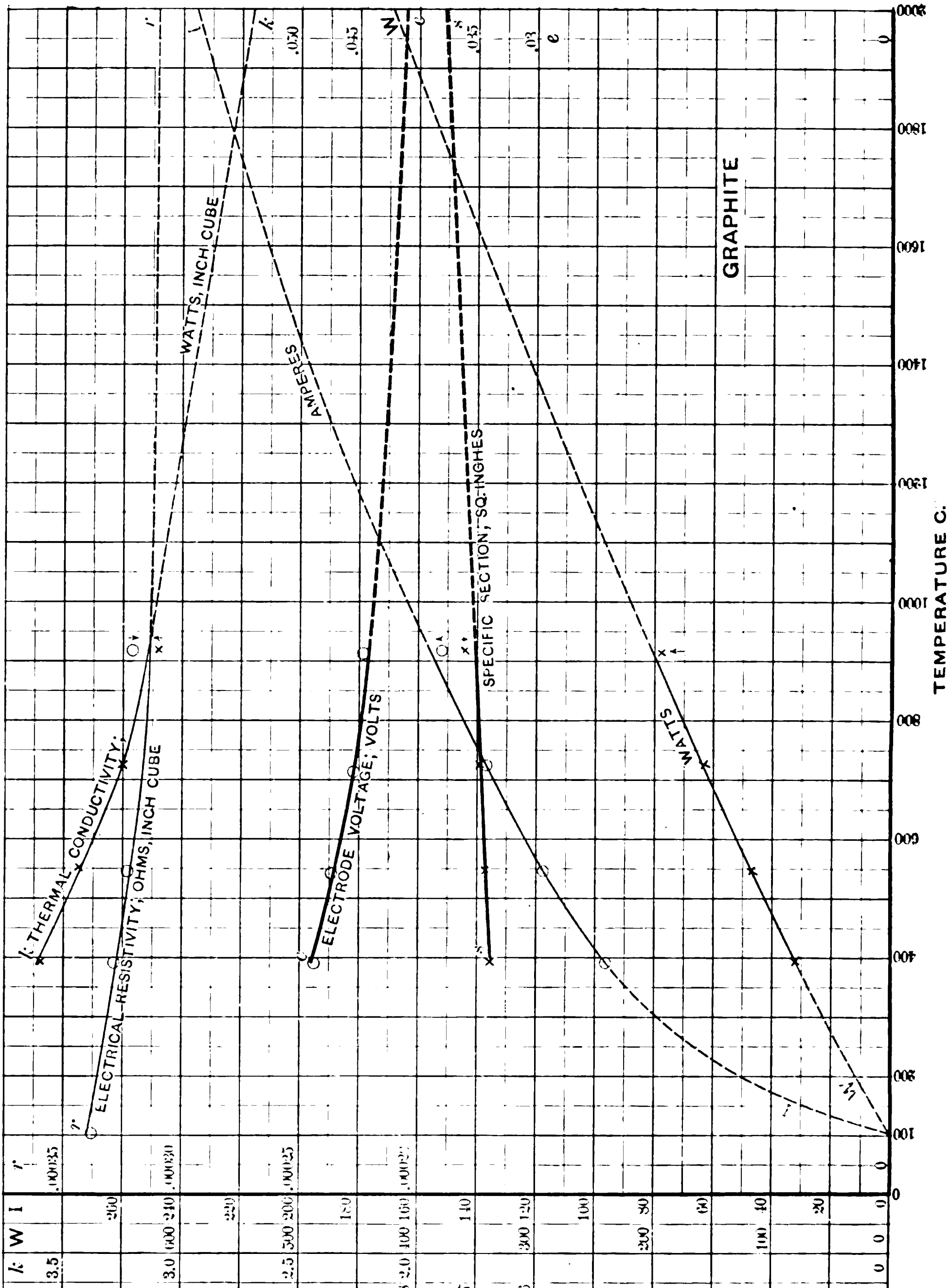


FIG. 2.—Electrode properties of graphite

concerned. In the second group, Figs. 5 to 9 all the results of one kind are reduced to the same scales, and may therefore be correctly compared quantitatively.

All these data refer to electrodes when operating under the condition that the hot end is raised by the current to the exact furnace temperature, and when the electrode, therefore, does not abstract any heat from the furnace. The values of all the specific properties (resistivities, conductivities, electrode voltages and specific sections) are the means under electrode conditions for the electrode as a whole; that is, they are the values of an equivalent electrode which as a whole will operate like the original one, but in which these properties have the same values throughout its entire length. The values for the currents, watts and current densities apply of course only to the particular size of the electrode tested and will be different for electrodes of other dimensions. The voltages, however, apply also to any other sizes of electrodes and to any other currents, provided only that the electrode is properly proportioned and is operated under the normal specified conditions and with the normal current.

Besides the actual numerical values of the various quantities, the point of special interest in this set of curves is whether the specific properties (that is, the properties per unit conditions) are sufficiently near to constant to be assumed so in ordinary practice, and also whether they rise with the temperature or fall, as this makes a difference in their behavior.

Carbon. Fig. 1. The current curve rises rapidly and nearly in proportion to the temperature. This means that changes in the current will produce nearly proportionate changes in the hot-end temperatures, hence variations in current affect the losses considerably, and a current which is considerably greater than the normal for which the electrode was designed, will tend greatly to overheat the electrode within the walls.

The watts increase nearly according to a diagonal line, as with all the other materials tested, except that for carbon there is a more pronounced deviation at low temperatures, which is also seen in some of the other curves, indicating that the properties of carbon follow somewhat different laws at the lower than at the higher temperature ; or perhaps, that at the higher temperatures, they follow laws similar to those which other materials follow at the lower ones.

The electrical resistivity diminishes, at first more rapidly, then less so, tending to become more nearly constant. A de-

creasing resistivity means that as the current heats the electrode, the heat generated per inch will become less and less at the hot end and greater and greater at the cold end, than it was before; hence the colder half will be heated more rapidly. This in turn signifies that the heat gradient will tend to approach a horizontal line from the hot end to near the cold one, and will then drop suddenly. Or in popular terms, the furnace heat will follow the electrode deeper into the walls. This seems to be one of the causes of the burning of the furnace wall in high-temperature furnaces in which carbon electrodes are used. A falling resistivity is therefore an undesirable quality for electrodes. A rapidly rising one would be far better; this is the case with iron, as will be seen below.

The thermal conductivity increases (it does not decrease as has been claimed by others) at first more rapidly, then less so, also tending to become more nearly constant. The surprisingly high values for the mean thermal conductivities are no doubt explained by the fact that the electrical resistivity falls quite appreciably with an increase of temperature. This in an electrode means that the larger half of the heat generated in the electrodes will be produced in the colder half, hence nearer the outlet, as explained above; it therefore has a shorter distance to travel in order to get out. The mean effective thermal conductivity calculated from the heat which flows out and from the dimensions of the electrode will therefore be increased, and will even be larger than an average of that taken at equally spaced points. But the value obtained in these tests is the real one which is wanted, as it is the one which applies to the electrode as a whole; it is the value which an electrode of uniform conductivities would have, which, as a whole, would operate like this one. This unequal distribution of heat in electrodes will be discussed by the writer more in detail in an article to be published elsewhere. The difficulty in calculating the mean from individual values lies in not knowing the heat distribution, that is, the temperature curve; also in the fact that these individual values for different temperatures have not yet been determined. The writer for these reasons recommended the present method as the more direct one by which to get the final results in the form in which they are wanted.

A rising thermal conductivity is an undesirable feature for electrode materials, as it tends to force the higher temperatures nearer to the colder end. Carbon unfortunately combines this

feature with a falling resistivity, both of which conduce to the same undesirable result.

The curves for carbon furthermore show that the electrode voltage, which is a true measure of the power loss, also increases with the temperature, but the rate is slower and slower, tending to constancy. It will be shown later that there are reasons to believe that it may even reverse again and fall at still higher temperatures. The loss in carbon electrodes therefore increases not only with the temperature, but also per degree of temperature; at least for these ranges. The chief conclusion, as far as our present knowledge goes, is that probably no great error would be made by assuming this important quality to be practically a constant, namely about 0.065 volt.

The specific section, which is a true measure of the size of an electrode, decreases rapidly at first and then more slowly, showing that carbon electrodes become relatively smaller for the higher temperatures; they are even smaller per degree at the higher temperatures. This is a good feature, and especially so for carbon because such electrodes are much larger than those of other materials, as will be seen later.

The electrode voltage and the specific section, are properties of the material, just as the specific resistance is, and if their values are constant or virtually so, calculations are simplified. The curves show that for most purposes in practice they may be assumed to be virtually constant for the higher values of this range of temperature.

The curves of the total voltages and of the actual size of the electrodes, being the ones which are the most important in practice, have for clearness been drawn apart from the others and will be discussed below in connection with Figs. 10 and 11.

The comparison of the quantitative values of the properties of carbon with those of other materials, is best made later in connection with Figs. 5 to 9.

Graphite. Fig. 2. The current curve rises more rapidly at first than for carbon, and in this respect graphite apparently possesses properties more like those of the metals. After this rise at the lower temperatures, it seems to approach more nearly to a straight line. The inclination of the latter part is less than for carbon, which indicates that for the same proportionate change in current the change of temperature produced thereby will be greater for graphite. From this it would appear to follow that a graphite electrode is more sensitive to changes of current than is one of carbon.

The curve of watts is practically a diagonal line, which shows that the watts lost in a given electrode will increase very nearly in proportion with the temperature drop, due to the current.

The mean electrical resistivity decreases slightly at first, and then seems to tend to constancy, at about 0.00031 in inch units (0.00081 in cm. units). It varies considerably less than for carbon, therefore the heat generated in the electrode will show a tendency to be more evenly distributed along the length, although the greater half of the $I^2 R$ heat is as in carbon, generated in the colder half of the electrode. Hence graphite stands between carbon and the metals.

A comparison of these mean values with those obtained by others when the whole rod is at the same temperature is of interest. It shows that these mean values are higher than the arithmetical means between the two extremes. This appears to be due to the fact that owing to a more rapidly decreasing thermal conductivity, the heat is forced back toward the hot end by the changes in thermal conductivity, more than it is forced to the cold end by the changes in the electrical conductivity. The result is that the average between the extreme temperatures would be greater than the actual; hence the mean resistivity found in these tests should be greater, which is the fact, if these data are correct. This places graphite among the metals in this desirable quality of forcing the heat back to the hot end.

The curve for the thermal conductivity shows that it falls as has already been stated. In this feature graphite differs decidedly from carbon (for which this curve rises) and is like the metals. The thermal conductivity falls more rapidly at first and then displays a tendency to become more nearly constant. Its rather high value is due partly to the falling electrical resistivity, as was explained above for carbon. It will be seen below that this brings its mean value even above that of iron, which has a rapidly rising resistivity.

The electrode voltage falls slightly, but seems to tend to what for all practical purposes may be assumed to be constant at about 0.040 to 0.045 volts. As this is a measure of the loss, it follows that the loss per degree diminishes slightly with the temperature instead of increasing, as it does with carbon. Graphite, therefore, is relatively to the temperature, more economical of power at higher temperatures than it is at the lower ones. This is due to the somewhat rapidly falling thermal conductivity.

The specific section is practically a horizontal line, and consequently may be assumed to be constant at about 0.0070 in square inches. This means that the size of the electrode relatively to the temperature is practically the same at high and at low temperatures; it does not decrease per degree, as with carbon, but even at the higher temperatures it is still much smaller. These comparisons are best seen below in other sets of curves.

Iron. Fig. 3. The current curve shows a marked peculiarity in that it is practically a horizontal line, differing radically in this respect from carbon and graphite. This is due no doubt to the very rapidly rising resistivity. As the hot end becomes hotter the resistance rises so rapidly that it cuts down the current again. Such an electrode is therefore nearly self-regulating for a constant current. A slight increase of current causes a very great rise in temperature. This fact was not fully realized during the progress of the test, in which the current was at one time raised too high, which apparently melted or perhaps even volatilized the hot end; this occurred before the run at the highest reading, hence the values obtained for the last point are not as good as the others, and were given less weight. After the test bar had been removed it was found that it had been melted at the hottest point and had even partly disappeared. This must have happened before the last run was taken, as that was still below the melting temperature. Anyone who repeats this test should be very careful to increase the current but very little at a time, and should not try to hasten the time of reaching the steady state by a temporary excessive current.

This peculiar property of iron, to change greatly in temperature with slight increases of current, also interfered with the intention to avoid the region of the recalescent point, about 700 degrees cent., as it was to be expected that the electrical and thermal conductivities might also take part in the peculiar physical pranks which iron plays at that temperature. It is doubtless due to this recalescent point that the curves are not as regular as are those of the other materials. They have a noticeable hump at about 700 degrees cent. But notwithstanding these disturbing factors, the general trend of the curves enables instructive results to be deduced.

In the exterpolated (dotted) parts of these curves, it has been assumed that the laws of variations continue to be about the same. It is not unlikely, however, that with materials which melt, like metals, as distinguished from carbon and graphite,

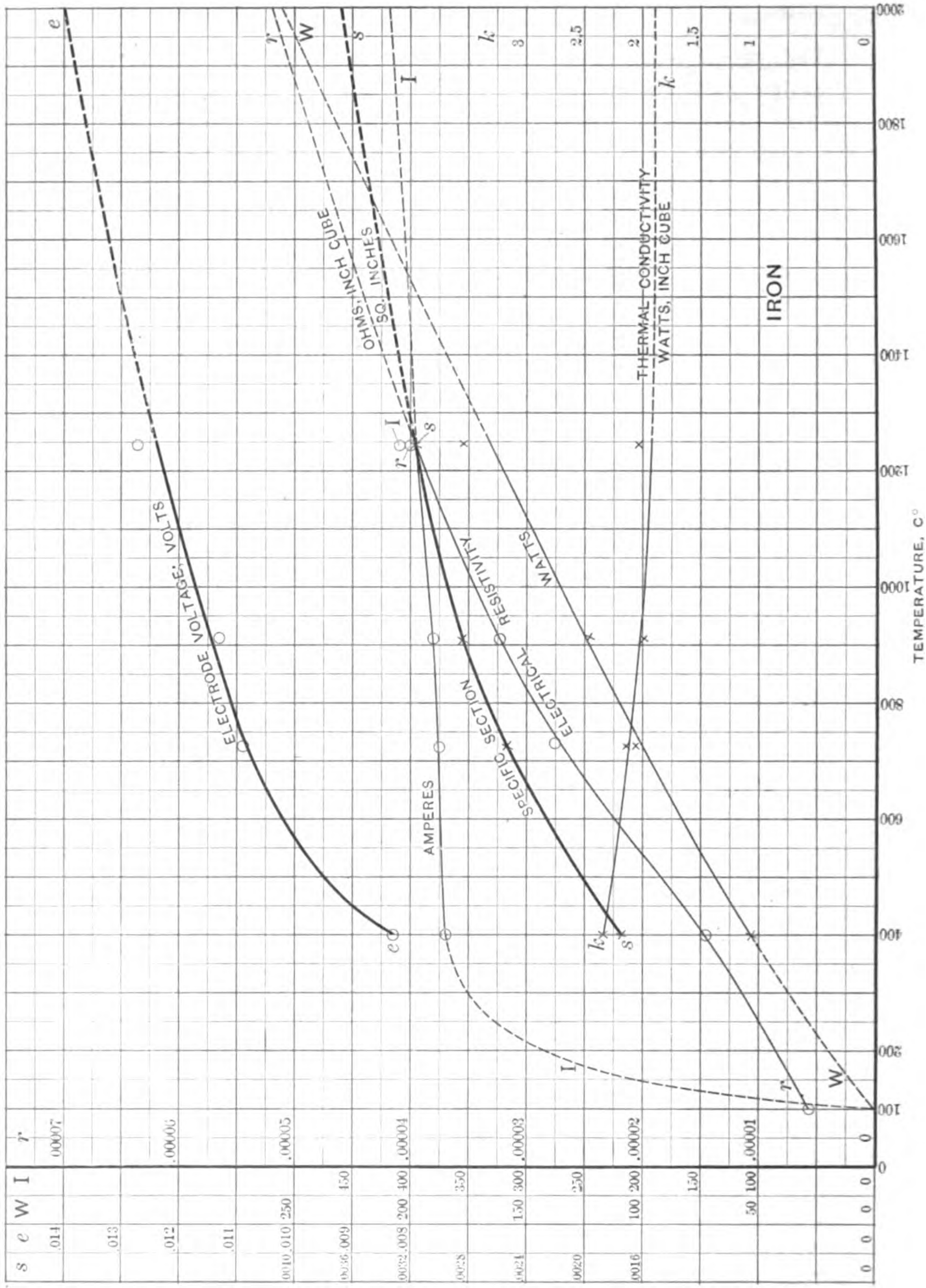


FIG. 3.—Electrode properties of iron

there may be decided changes of these physical properties at the melting point. This can be determined only by experiment, and tests with molten columns the cross-section of which must remain constant, become difficult. Moreover, unless they were made on a large scale they would be seriously interfered with by the so-called "pinch effect", which would break the column unless it was very securely confined. Under the circumstances the exterpolated values may be of at least temporary use until someone has made the actual tests. But it should be remembered that they are nothing more than exterpolations.

The curve of watts is as usual virtually a diagonal.

The electrical resistivity rises greatly, and roughly in a straight line with only an indication that the rate probably falls at higher temperatures. This rapidly increasing resistivity is a very desirable feature for electrodes, as it forces the heat back to the hot end, as was explained above.

The thermal conductivity falls, which is also a desirable feature. It is of interest to note that for iron both conductivities vary in the desirable way, while for graphite only one does (the other however being nearly constant), and for carbon, they both vary in the undesirable way. Although the thermal conductivity of iron falls, the amount is but slight and it may be assumed to be practically constant at about 1.9 to 2.0 in watts, inch cube units.

It will be noticed that the mean thermal conductivity is less than that of graphite. This may not agree with comparisons of the usual constants at specific temperatures; the explanation of the difference unquestionably lies in the fact that the heat is forced to the hot end more in iron than in graphite, as has been explained. The greater part of the heat having to travel a greater distance to get out, an iron electrode is rendered equivalent to one having a lower conductivity than the iron has at those temperatures.

Owing to this combined falling conductivity and rising resistivity, it seems that the temperature curve for iron must fall quite rapidly at the hot end and then approach the horizontal for the greater part of the length. This confines the high temperatures to the end near the furnace where they belong. It moreover has a tendency to make the temperature gradient in the electrode more like that in the walls, which signifies that little or no heat passes from one to the other. But one of the most important results is that when there is an excessive cur-

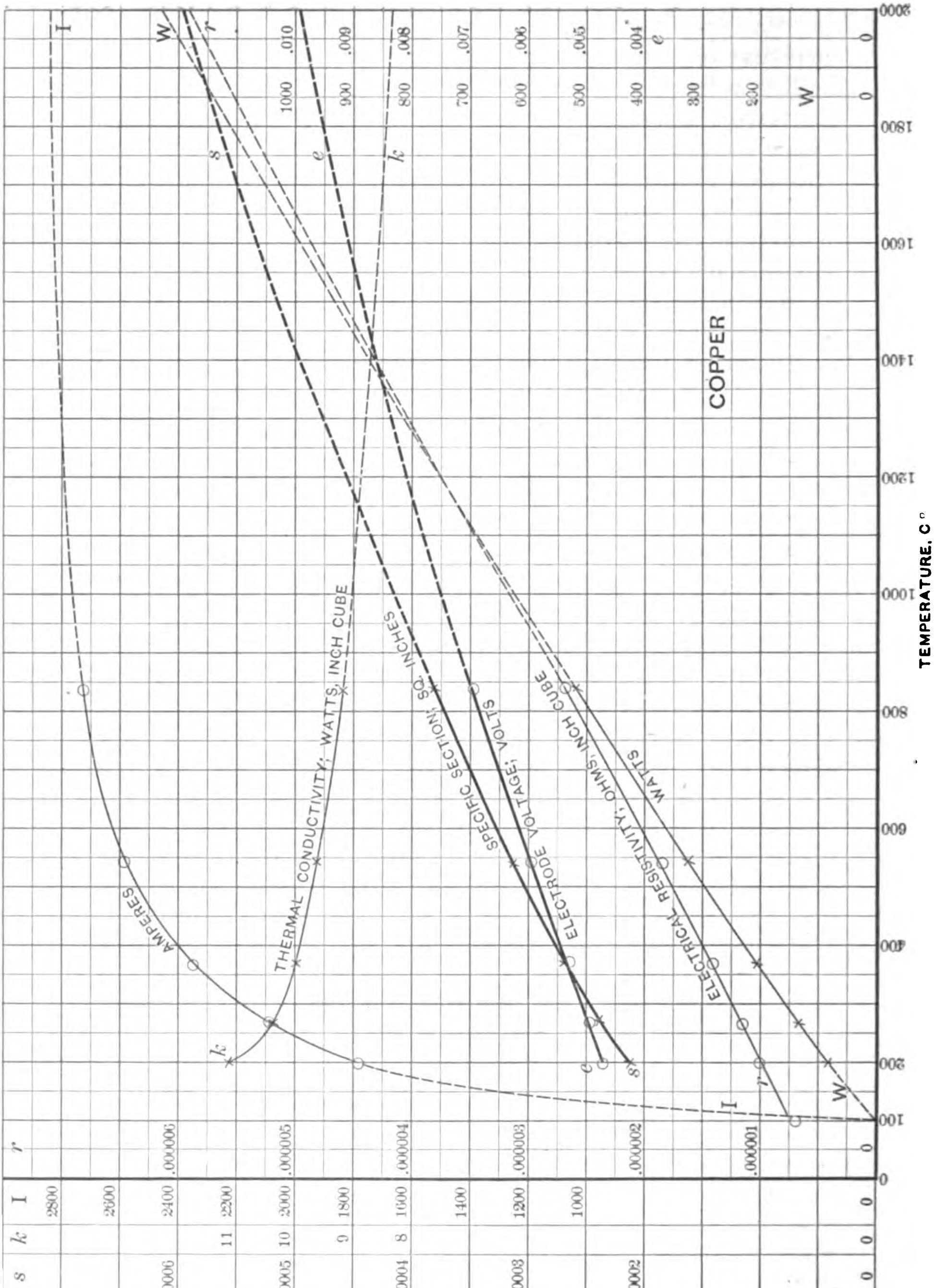


 FIG. 4.—Electrode properties of copper

rent, which tends to heat the electrode within the walls to a higher temperature than that of the furnace, this high temperature point will be very near the furnace, far nearer than it would be for carbon, for instance.

The electrode voltage rises quite decidedly. This means that iron electrodes are relatively less economical in power at the higher than at the lower temperatures; there are no indications of a constancy of the value of this property within these ranges.

The specific section also rises at about the same rate, showing that the size also becomes less favorable at the higher temperatures.

The test bars were cold rolled, mild steel.

Copper. Fig. 4. The tests with the copper electrodes were the best of the series. This was due partly to the fact that the currents, being very large, were better adapted to the output of the dynamo; partly to the fact that copper had a thermal conductivity so very much better than that of the surrounding heat insulating material, that the proportion of the loss to the surroundings was least; and lastly, because it was the last test of the set and the writer was enabled to embody the experience gained in testing the other materials.

The current curve rises extremely rapidly at first and then apparently tends rapidly toward the horizontal; it seems to be similar in shape to the one for iron at lower temperatures. It therefore appears that this shape may perhaps be characteristic of the metals. The last point was very near the melting point. hence the exterpolated values are based on the possibly incorrect assumption that no radical changes take place in these properties at the melting point.

The curve of watts is again practically a diagonal.

The electrical resistivity rises very rapidly and in virtually a straight line; copper resembles iron in this property, and the resistivity rises even slightly more rapidly in percentage. What was said about iron in this respect applies therefore also to copper. The heat will again be forced to the hot end.

The thermal conductivity also falls, as in the case of iron, only to a greater degree. This and the rising resistivity should make copper a very suitable electrode material for the temperatures for which it could be used.

The electrode voltage rises in almost a straight line proportion. So does the specific section. It is therefore like iron in these respects.

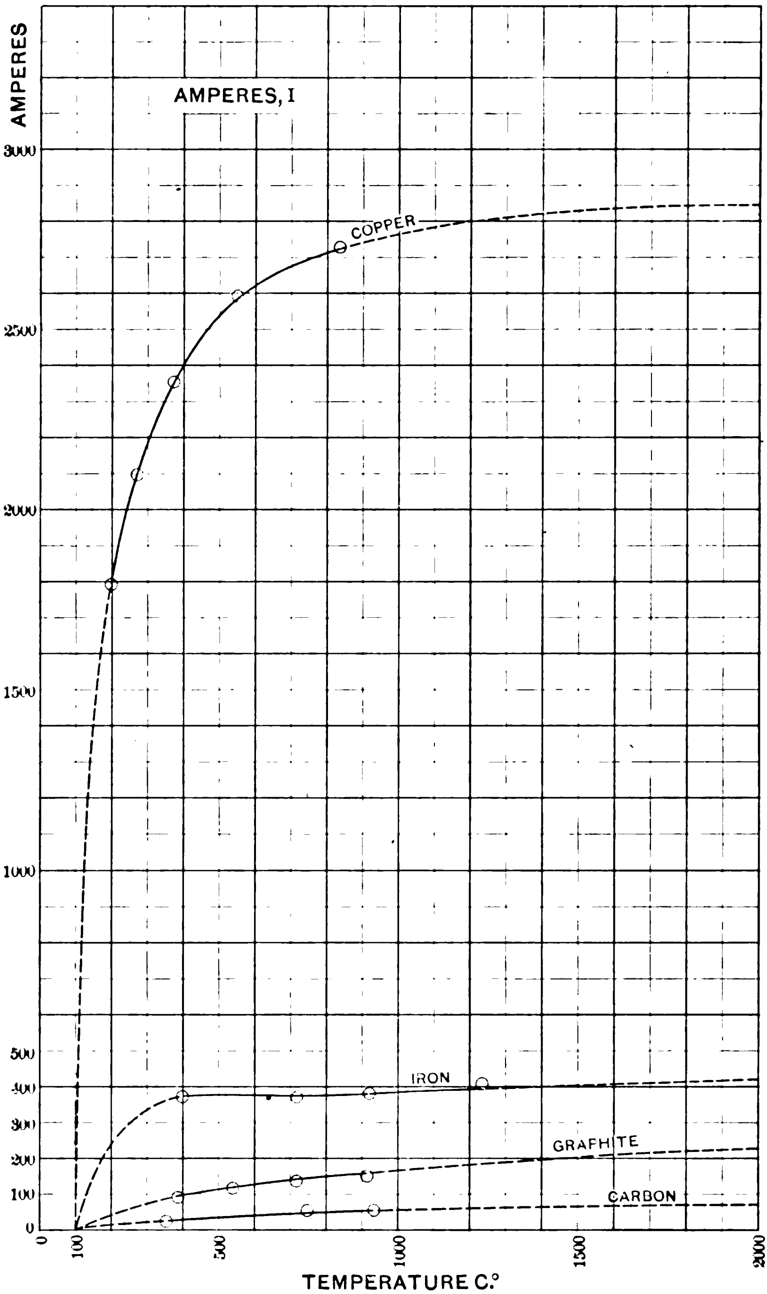


FIG. 5.—Current for different materials

Comparisons. In all the above curve sheets the scales were chosen as large as the space permitted, hence they are all different. In order to compare the different materials with each other quantitatively all the curves for each property have been redrawn to uniform scales in Figs. 5–9.

Current. Fig. 5. These curves explain themselves. They show that at about 1500 degrees cent. a graphite electrode will carry over 3 times as much current as will one of carbon of the same size; iron will carry over twice as much as graphite or nearly seven times as much as carbon; and copper is enormously better than any of the others, its current capacity being about 45 times that of carbon or 14 times that of graphite. With what losses these electrodes carry these currents will appear later.

The curves also show a tendency to become horizontal. The actual numerical values refer to $\frac{5}{8}$-in. round electrodes and to no others, although relatively the currents would always have the same ratios.

Current densities. The cross-sections in all the test rods being the same, these curves also represent the relative values of the current densities. The actual values are given in Table I. Some of them will be seen to be exceedingly high.

Watts. Fig. 6. The curves for all four materials are seen to be nearly diagonal lines, indicating that the watts increase nearly in proportion to the temperature required. In order to show how little they differ from the true diagonals, the latter have been added as thin lines to the last points. The difference is greatest with carbon. It can be shown that in so far as the real curve differs from the exact diagonal, in so far does the thermal conductivity vary from a horizontal line, that is, from constancy; if these curves approach the diagonal more nearly for the higher temperatures, as they seem to, it means that the thermal conductivities approach constancy for those higher temperatures.

Moreover if the bend is above the diagonal as it is for copper, graphite and iron, it signifies that the thermal conductivity falls, while if below, as for carbon, it rises. Furthermore, it can be shown that the thermal conductivity is proportional to the tangent of the angle which the diagonal to any point makes with the horizontal.

Further than this, the curves should not be compared, as they might mislead. Quantitatively they refer only to those particular electrodes $\frac{5}{8}$ in. in diameter, and to no other size. While the

watts lost for copper are very much greater than for carbon, the current delivered was also far greater, and the relative loss was far less than for carbon. This is shown better in the later curves.

Electrical resistivity. Fig. 7. These curves show strikingly the quantitative relations, it being nearly impossible to show copper and carbon on the same sheet. A low electrical resistivity is a desirable quality in electrodes, both in economy of power and in the economy of materials. It shows why copper is so very much better than carbon, when it is possible to use it.

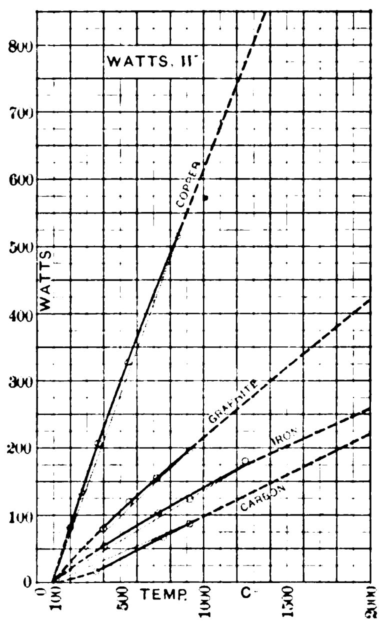


Fig. 6.—Watts for different materials

Iron is near copper, and graphite is much nearer the metals than carbon. A rising resistivity is a good feature while a falling one is a bad one.

An interesting point is that the lines for carbon fall rapidly, those for graphite also fall but very slightly, while those for the metals rise. Their relative inclinations make it appear as if they tended to meet at some very high temperature in a common point somewhat below graphite, at which point they would all have the same resistivity. At 1400 degrees cent., the relative values are about: copper 1, iron 10, graphite 72, carbon, 340.

Thermal conductivity. Fig. 8. The thermal conductivities differ far less than the electrical resistivities; moreover the usual order is here reversed, graphite being now next to copper. They again all seem to tend to meet in a point, this time iron being the more central one. The relative values at 1400 degrees cent. are about: copper 1, graphite 0.34, iron 0.22, carbon 0.17. It may be repeated here that a falling thermal conductivity is a good feature and a rising one is a bad one; also that a high thermal conductivity reduces the size of an electrode but increases the

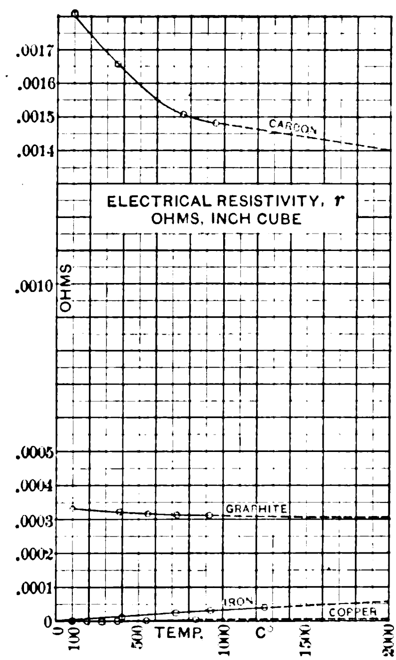


FIG. 7.—Mean electrical resistivities for different materials

loss; hence it is a good or a bad quality depending upon which of the two economies one desires. There are other properties which are better measures of excellence of an electrode material; they will be discussed below.

Electrode voltage. Fig. 9. This is the specific property which is a true measure of the minimum watts lost in an electrode, when it is properly proportioned. Its significance has been described above.

The curves are shown in thin lines. They all show a tendency

to rise except for graphite which alone possesses the good property of a falling curve. As all these specific quantities seem to tend to meet at some very high temperature, it may be that carbon which is the only exception, will also fall again at higher temperatures, as indicated.

Iron is now nearly as good as copper and much better than graphite, although the difference seems to grow less at higher temperatures. The lines for graphite and carbon depart at first, but then remain nearly parallel. The relative values at about 1400 degrees, are about: copper 1, iron 1.5, graphite 5, carbon 7.5.

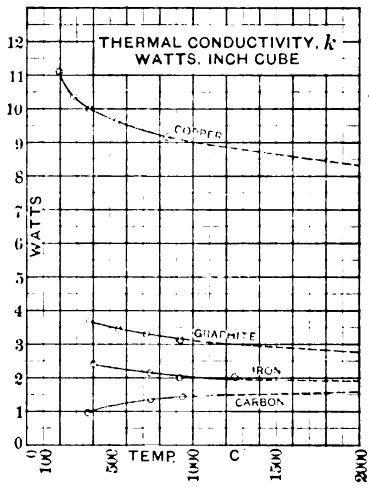


FIG. 8.—Mean thermal conductivities for different materials

Specific section. Fig. 9. This is the specific property which is a true measure of the size of an electrode, when properly proportioned. Its significance has been described above. The curves are shown in heavy lines. They all tend to rise except for carbon; and again they seem to tend to meet. Copper as usual makes the best showing, and graphite is nearer the metals in this respect than it was for the electrode voltage. Carbon is far from the others, showing that such electrodes must be made very much larger. For about 1400 degrees cent. the relative values are about: copper 1, iron 6.6, graphite 14.6, carbon 45.

These two qualities have been drawn on the same sheet to facilitate comparisons. Carbon electrodes are seen to be both

large and wasteful of power, those of graphite are much smaller and while they consume less power, the difference is not as great as that in the sizes. Copper is best in both respects, and iron comes next in both qualities, being also better in both than graphite, particularly in the economy of power.

Actual losses and sizes. Figs. 10 and 11. The electrode voltage and the specific section are the two physical constants which the writer suggests using instead of those formerly employed. Like most other physical constants they vary somewhat with the temperature, though some of them only very slightly; but

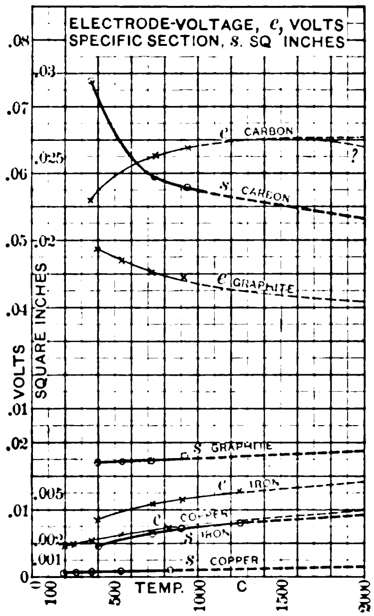


FIG. 9.—Electrode voltages and specific sections

they nevertheless belong correctly under the heading of physical constants, which can for many calculations be assumed to be constant, or have the differences allowed for, just as is done with resistivities in ordinary electrical conductors.

But as was explained above, the usually required calculations may be considerably simplified and reduced to a mere simple multiplication, by using instead a tabulated set of numbers. These are no longer "constants" in the usual sense of the term, because from their very nature they must have greatly different values for different temperatures, although for some

TABLE II

CONSTANTS FOR CALCULATING ELECTRODES

Temperature		*E* Watts per ampere				S^1 Square inches per ampere per inch length				S^1 Square centimetres per ampere per cm. length			
Cent. degrees	Fahr. degrees	Carbon	Graphite	Iron	Copper	Carbon	Graphite	Iron	Copper	Carbon	Graphite	Iron	Copper
400	752	1.00	0.85	0.145	0.095	0.00165	0.00040	0.000103	0.000016	0.0042	0.00100	0.00026	0.000041
600	1112	1.38	1.04	0.225	0.140	0.00114	0.00031	0.000102	0.000015	0.0029	0.00078	0.00026	0.000037
800	1472	1.68	1.19	0.295	0.184	0.00090	0.00027	0.000101	0.000014	0.0023	0.00068	0.00026	0.000036
1000	1832	1.93	1.32	0.350	0.226	0.00076	0.00024	0.000098	0.000014	0.0020	0.00061	0.00025	0.000036
1200	2192	2.15	1.43	0.410	0.270	0.00069	0.00022	0.000094	0.000014	0.0018	0.00056	.00024	0.000035
1400	2552	2.36	1.52	0.460	0.310	0.00062	0.00020	0.000092	0.000014	0.0016	0.00051	0.00023	0.000035
1600	2912	2.53	1.62	0.510	0.351	0.00057	0.00019	0.000089	0.000014	0.0014	0.00048	0.00023	0.000035
1800	3272	2.68	1.71	0.565	0.391	0.00053	0.00018	0.000087	0.000014	0.0013	0.00046	0.00022	0.000035
2000	3632	2.83	1.79	0.610	0.430	0.00049	0.00017	0.000085	0.000014	0.0012	0.00044	0.00021	0.000035

materials and ranges the curves representing them are very nearly straight lines.

If, therefore, the designer has such a table of values at hand, he will no doubt prefer those values to using the physical constants. These two sets of figures give the watts per ampere, and the square inches of section per ampere per inch of length, for each temperature. Hence to find the minimum loss in watts for any given material and temperature (the cold terminal temperature being 100 degrees cent.) one merely multiplies the corresponding number of " watts per ampere " from the table, by the current in amperes, while to find the proper section in square inches it is necessary only to multiply the corresponding " section per ampere per inch length " by the current and the length in inches. The calculations are so simple that they may in many cases be made mentally. These values are given in Table II and are shown graphically in Figs. 10 and 11.

As shown above, the watts per ampere are in fact merely the voltages (in volts) between the two ends of an electrode when operating under the condition in which there is no loss of furnace heat. Hence these are not deduced figures, but are actually measured during the test, (being half the measured voltages of the two electrodes), while the figures for the sections per ampere per inch length are merely the cross sections of the test rods divided by the length of the electrode (half the length of the double ones used in the test) and by the current.

It will be seen therefore that it is not at all necessary to determine or even to consider either the electrical or the thermal conductivity in electrode problems, if these simple data are at hand. And the writer's conclusions therefore are, that as little or no reliable data of any kind exists for the higher temperatures, and must therefore be ascertained, it is much simpler to determine and use these two new factors, instead of determining and using the mean conductivities. It is also infinitely simpler than the former method of determining the conductivities at each of various temperatures and then by means of more or less complicated and approximate formulas calculating the final results, with the uncertainty involved in all approximate algebraic deductions in which we do not always know how much the originally small, allowed errors may be magnified during the algebraic processes.

The writer's present method goes directly from the experimental result to the desired application in practice, without

involving any assumptions other than that the *relative* distribution of the heat in the electrode for any given material and end temperatures, is the same for all cross-sections and lengths, (which is believed to be exactly correct under the assumption of no heat loss to the walls), and that the relative heat loss to the walls, whatever it may be, is approximately independent of the lengths and sections, (which is known to be not exactly true but probably sufficiently so for all practical purposes).

It should be noticed that no assumption is made that the heat loss to the walls is the same for all materials; on the contrary it will be different, perhaps appreciably so because, as was seen above, some materials (like carbon) have the property of forcing the high temperatures toward the cold end, while others (like iron) force it back to the hot end. For this reason the temperature gradients will be quite different in the two cases, and the loss to the walls, if it is large enough to be considered at all, will therefore be different for different materials; but in the present method this difference is taken care of in the tabular data, and needs no further consideration.

The curves for these two final quantities are given apart from the others in Figs. 10 and 11. In Fig. 10 they have been drawn to different scales so that they are nearly superimposed, thus enabling their relative inclinations or percentage values to be compared better with each other, while in Fig. 11 they have all been drawn to the same scale, so that they may be compared quantitatively.

In Fig. 10 it will be seen that the curves E, which measure the minimum loss, or the watts per ampere, all have a family resemblance, except in the case of graphite; in fact with slight changes in the scales, those for iron, copper and carbon may nearly coincide, except at their lower temperature values, and this difference may be due to the experimental determinations which were not carried out quite as carefully at the lower temperatures for carbon and iron, as for copper. Even graphite might perhaps be brought into line by a change in the horizontal scale, which would mean that the temperature would have to be multiplied by a coefficient, or have a different exponent.

This family resemblance, and the fact that all these curves must have a zero and an infinite value, of course suggest the possibility of a common formula for all, differing only in its coefficients. But this is beyond the purpose of the present paper; the results obtained in this interesting direction will be made the subject of another discussion.

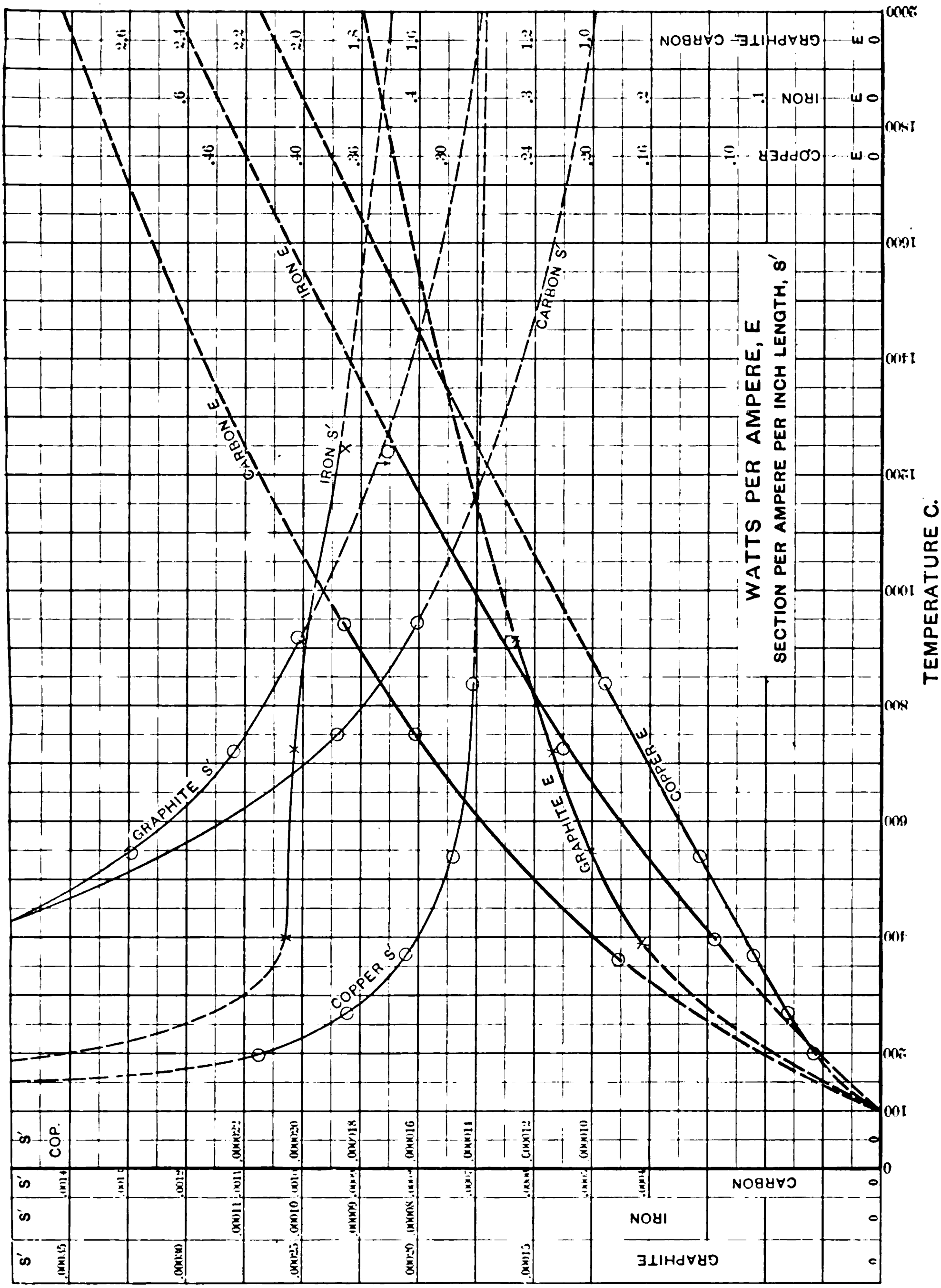
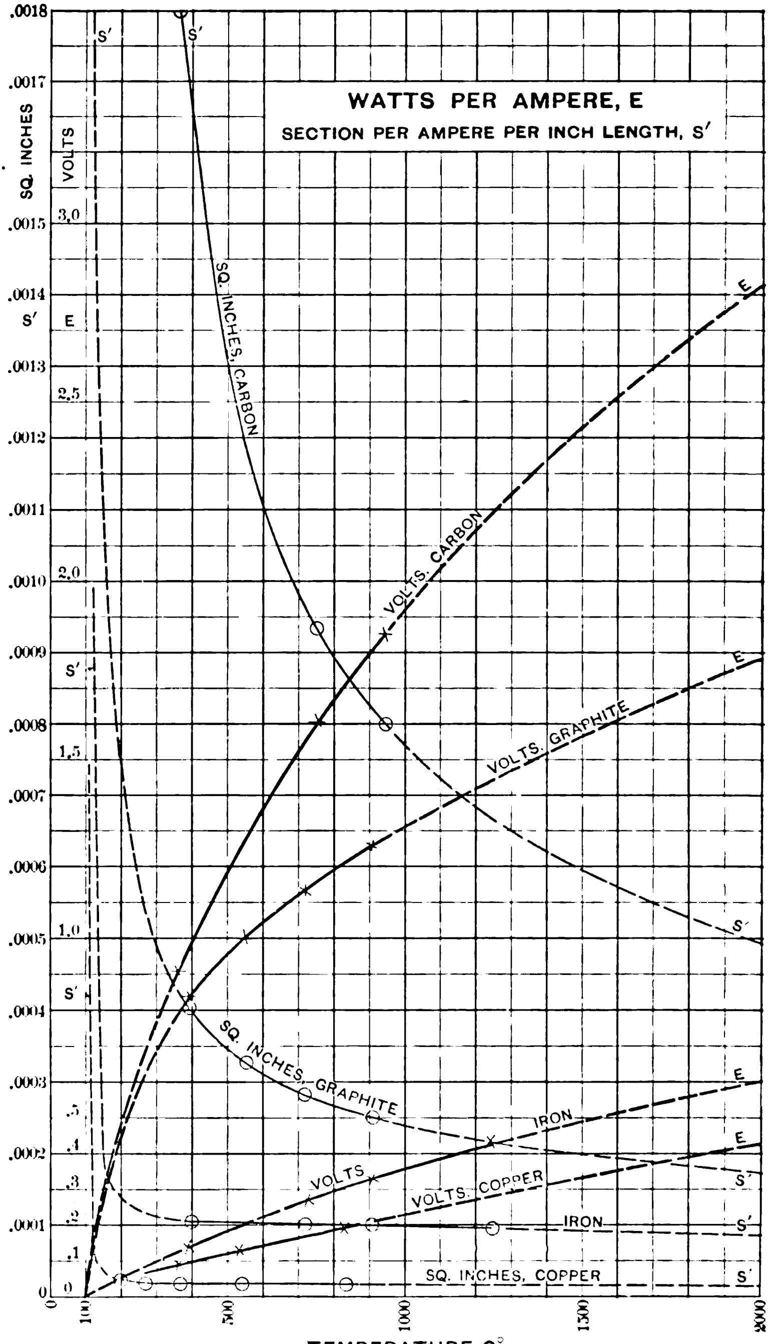


FIG. 10.—Losses and sizes; superimposed



[326] FIG. 11.—Losses and sizes; same scale

The marked difference of the graphite curve means that the losses in graphite electrodes do not grow as rapidly with the temperature as they do for all the other materials. This, of course, is a very good quality, especially for high temperature furnaces. For all the others the relative increase of this loss is about the same. It is of interest to note that copper and carbon, the two extremes in all other comparisons, are here very nearly alike in their percentage variations.

A comparison of these same curves E in Fig. 11, (the heavy line curves) shows the quantitative relations of the actual losses per ampere. The much greater loss for carbon is quite striking; but of course there are many cases in which metals are excluded by the very nature of the furnace. Consequently, tempting as it may be, the good quality of the metals cannot be taken advantage of. The relative values at 1400 degrees cent. are about: copper 1, iron 1.5, graphite 5, carbon 7.5; the same, of course, as for the electrode voltage.

The loss for carbon is seen to be 1.55 times that for graphite. This is interesting in view of the claims that have been made that graphite is more wasteful of power than is carbon, even ten times as bad. Hence either the experimental data on which that result was based were in error, or the method of deducing the result from them was incorrect; or else the curves change very radically at the higher temperatures, which seems hardly likely. If the present exterpolations are correct, this difference in favor of graphite becomes even greater at the higher temperatures.

Returning to Fig. 10, the thin line curves S' (the section per ampere and per inch) will also be seen to have a family resemblance, and as they also must have values for zero (100 degrees in this case) and infinity, the possibility of a general equation differing only in coefficients or exponents, suggests itself for this relation also.

If equations can be deduced for both S' and E, it will be possible to calculate both the conductivities from them, as one is proportional to the product, and the other to the quotient, of the conductivities. The coefficients for S' and E are, of course, determined experimentally, as in the present case, and the conductivities will therefore be functions of these coefficients.

The exception in the S' curves is iron, but in general the two metals are similar to each other, as are the two non-metals, the two pairs differing somewhat.

Comparing them quantitatively in Fig. 11, the family resem-

blance is again apparent, the curves being evidently asymptotic to both ordinates, care being taken to deduct the 100 degrees cent. for the cold terminal temperature.

Carbon electrodes are again shown to be far larger than the others. The relative values at 1400 degrees are about: copper 1, iron 6.6, graphite 14.6, carbon 45, the same as for the specific sections. In this feature graphite is more like the metals and differs more from carbon than in the losses. The section for carbon will be about 3 times that for graphite. This difference in size, however, seems to diminish for higher temperatures, if the present exterpolations are correct.

Comparing both these important factors, it will be seen that graphite is better than carbon in both loss and size, especially in size. Copper is best in both and carbon worse in both, while iron is closer to copper in both than it is to graphite.

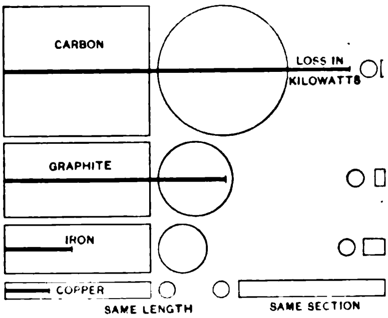


FIG. 12.—Comparison of sizes and losses

This final comparison is shown in a practical way in Fig. 12, in which the sizes and losses in electrodes of the different materials are drawn to scale for a given case, in which the current is assumed to be 10,000 amperes and the end temperatures 1400 degrees cent. and 100 degrees cent.

In the first set, to the left, the length is made the same for all, namely 10 in., hence the sections will be different, and in the proportions of 1, 6.6, 14.5, and 45, the same as above given. The actual sizes in square inches are: copper 1.38, iron 9.16, graphite 20.1, carbon 62. It will be seen that the proportions for carbon are practically impossible.

In the second set, to the right, the cross-section is made the same, the lengths being then different. They are in inches: 10, 1.51, 0.69, 0.22, dividing which by 10 gives their relative

values based on copper. That for carbon is again impossible, as are also those for graphite, and perhaps iron.

The losses in kilowatts per electrode are indicated by the lengths of the heavy black lines, which of course apply equally well to either of the two sizes for the same materials. They are in kilowatts, about: 23.6, 15.2, 4.6 and 3.1, or in the ratio of 7.5, 5.0, 1.5 and 1.

When the ratio of the section to the length is a constant, as in this case, the length increases more rapidly than the diameter. Hence to give the carbon electrode a suitable shape for handling, it must be made still larger, and considerably so. In comparing practical electrodes this feature should be considered, and it will increase still more the difference between the sizes of the carbon and the others. When finally the volumes are figured out, the differences will be found to be very great. But even when thus correctly proportioned the losses will still be much greater for carbon, as they are the same for all sizes, provided the relation of the section to the length is the same.

It is evidently not proper, as has been claimed, to lengthen the carbon electrode of the section shown, so as to give it a better shape, and to think that this merely means a small sacrifice in efficiency. Such a lengthening will evidently result in developing a high temperature within the walls, higher and perhaps much higher even than the furnace temperature. This would be likely to burn out the furnace wall, which would be fatal to successful operation. If it is made smaller and shorter the proportions will be still worse, as is seen in the upper right hand illustration. Consequently there seems nothing left to do but to make it much larger and longer.

This brings out another wrong deduction which has been made by others, based on our former incorrect rules. Suppose the carbon electrode in this Fig. 12 had been made with the same section but 20 in. long; it is evident from the results of the present analysis that a high temperature point, higher than that of the furnace, and probably very much so, would develop at a point somewhere between the furnace, and a point 10 in. from the cold end, because 10 in. is the correct length for that section. This would burn out the walls. The conclusion drawn from our former ideas was that the current density was too high, when the fact is that the electrode was too long for that section. The current density had nothing to do with the failure, because if the electrode had been made half as long instead of as long again,

it would have been too cold and would have chilled the furnace, although the current density were the same. Furthermore if the electrode had been made half the section and length shown in Fig. 12, it would have operated properly even though the current density had thereby been doubled. The current density, therefore, was not the cause of failure; it has often been made responsible for faults which were really due entirely to errors in the length.

Summary

The final results of this rather lengthy investigation are briefly as follows, as far as they interest the designer.

The underlying feature is that the electrode shall not chill the furnace, nor develop a high temperature point within the walls at which the temperature is greater than in the furnace. Hence the hot-end temperature should be as nearly as practicable equal to that of the furnace.

The current and furnace temperature are always given in the specifications. The material and either the length or the section (but not both) may also be specified, but preferably all three should be left to the designer. The voltage and loss cannot be specified, as they are determined by the current, temperature and material.

The length (that is, the essential length, not including additions to either or both ends for other purposes than to get the energy through the walls) may be determined solely by the thickness of the furnace walls; but as this affects the cross-section, some latitude should be left in case the corresponding section is found to be too large or too small to be practicable.

The section in square inches is then determined at once by multiplying the proper temperature value of S' from Table II by the current in amperes and by the length in inches (formula 13). If this is too large or too small to be practicable, the length may be changed and the section may be re-determined. The quotient of the section divided by the length is a constant for any specified conditions, (numerically equal to S' from the table multiplied by the current) hence they may both be increased or decreased in the same proportion.

Should this table of values not be available and the specific section be known, formula (14) should be used for calculating the section. If this is also not known, then use the conductivities in formula (7). Great accuracy is not necessary when one is near the correct result, as an error in section near that point produces a relatively much smaller error in the loss.

The loss in the electrode in watts is entirely independent of the section or length adopted, provided only that their quotient is approximately as above. It is calculated in watts by multiplying the corresponding temperature value of E in Table II by the current (formula 10). If this table is not available, we may use the electrode voltage in the last part of formula (5). If this is not available either, then use the conductivities in the preceding expression of formula (5). This loss is for one electrode and it is the least possible under those conditions.

When the current for a furnace varies appreciably, the calculations must of course, be made for some assumed normal value, remembering that whenever it is less than that, the electrode will chill the furnace more or less; and whenever it is greater the electrode will get hotter within the walls, and in both cases the total loss will be greater.

In operating a furnace, if the electrode is found to chill the product, it is either too short, or too large in section. If on the other hand it is found to produce excessive temperatures within the walls, it is too long or of too small section. The current density is not a determining factor.

The hotter the outside terminal is allowed to get, the smaller the loss, but the larger the section or shorter the electrode.

When the proportions turn out to be large in section and short in length (as for instance with carbon for large currents as in Fig. 12) the relative proportions may be improved by increasing both length and section. On the other hand, if the electrode is abnormally long and small in section (as for instance with iron or copper and small currents) then if the section cannot be made smaller, there seems to be nothing left to do except to sacrifice some of the loss by making the electrode shorter and it will then chill the furnace more or less.

The additional lengths of the electrode necessary for the terminals, for feeding, or for the distribution of the current in the inside, must be calculated separately, as they are determined by entirely different laws and conditions; the above refers only to the essential part which is necessary to get the current into and out of the furnace as well as possible. The above length must therefore never include the long external part outside the furnace, for feeding purposes. Such a part radiates heat to the air and therefore follows entirely different laws of proportions. A redeeming feature of such a case is that the outside temperature used to determine the proportions of the essential part, may

be allowed to be very high, probably limited chiefly by oxidation thereby reducing the total loss which has been increased by the long external part.

Summary of previous discussions. The description of this new way of attacking the problem of the proportioning of electrodes, given by the writer briefly in May, 1909, and more in detail in October 1909, has given rise to long discussions and attacks. Some of the purely technical parts were of interest and value and will be summarzied briefly below. The rest of the discussion is of no general interest as it consisted of the usual unsubstantiated claims of priority made by those who suddenly found that they had known it long ago but had not given their knowledge to others or used it themselves. It contained also the assertions of those who claimed, after the method was described, that it was obvious though this had not occurred to them before; also the statements of those who maintained that on account of some academic minutia it was obviously fundamentally incorrect, although they could not substantiate their claims with actual figures; and the assertions of others who thought that the results were of no value because the necessary physical properties of the materials were then not yet known; etc.

One of the parts of the discussions which was of value referred to the magnitude of one of the corrections to which reference was made in the original paper, due to the simplified premises. This correction referred to the effect of the variation of the conductivities with temperature, and therefore is in the nature of a refinement or second approximation. Another important part was an ingenious graphical method devised by Dr. A. E. Kennelly,* for representing and studying the relations of the quantities involved.

Concerning the temperature correction, Dr. Kennelly has shown in a very able paper† that under certain approximate premises, (including a uniform fall of temperature in the electrode) this correction factor is zero when the electrical resistivity varies according to a straight line law (the thermal one being constant). The correct mean value then is the arithmetic mean between the two extreme values at the two end temperatures. Also that the same is true when the thermal resistivity alone

*Trans. Am. Electrochem. Soc., Vol. 16, p. 297.

†A paper "On the Modifications in Hering's Laws of Furnace Electrodes Introduced by Including Variations in Electric and Thermal Resistivities" to be published in these PROCEEDINGS.

varies in this way. Also that when both vary in this way, the total loss is least when half of the heat flow at the cold end is joulean heat and the other half is conducted from the furnace; the remainder of the joulean heat is assumed to flow toward the furnace, thereby tending approximately to balance the furnace flow, hence a "very little heat will flow into or out of the furnace." This means that the condition of no loss of furnace heat under those approximate premises, is only a close approximation to the condition of minimum loss, instead of being identical, as it is with constant conductivities.

Dr. E. F. Roeber* has attempted the complicated mathematical solution of the case when both conductivities vary according to a straight line law, and has carried it up to, but not including the integration. Although this unfinished formula is probably too complicated for use in practice by engineers, it shows that for given materials at stated temperatures the correction factor is merely the numerical coefficient, and that the relations between the variable factors remain the same. Dr. Roeber also finds that when the electrical conductivity is constant and the thermal conductivity alone varies by a straight line law, this complicated formula reduces to the simple original one in the writer's paper. This indicates that it is largely the variation of the electrical conductivity which gives rise to a correction factor, a fact which the writer has since shown in another paper in a different way.

Dr. H. C. Richards† gives a very interesting solution of the integration for the complete case when both conductivities vary by straight line laws, and gives the first two terms of the series of coefficients. This enables the correction factors to be determined, when the conductivities and their variation with temperature are known. By means of this interesting solution it was shown by the writer‡ that even for very great variations in the conductivities, the corrections on which some of the critics based their unsubstantiated claims that the writer's approximate formulas were very incorrect and even "fundamentally wrong", were in fact quite negligible in practice.

The writer takes this opportunity to express his appreciation of these able mathematical solutions by Dr. Kennelly, Dr.

* "Electrode Losses in Electric Furnaces," Trans. Am. Electrochem. Soc. Vol. 16, p. 363. See formula (5) p. 367.

† Trans. Am. Electrochem. Soc. Vol. 16, p. 304.

‡ *Ibid*, p. 310.

ichards, and Dr. Roeber, which show that differences between the writer's simple first approximation of the complete problem and the second approximation, are not great, and in part do not exist at all. Their work was done before the present experimental determinations had been undertaken, and before some of the simplifications described in the present paper had been made.

Those who, on the other hand, attempted to belittle and discredit the results of this investigation, brought up minor points which were either based on an incomplete reading of the original paper and are answered in the present paper, or were based on academic points which it is believed the practical engineer can safely neglect or allow for, as he does in most other construction work. The present investigation was made from the standpoint of the engineer and not from that of the academician or the mathematical physicist whose enlargement of negligible minutia is apt to obscure the main practical issues; nevertheless the analytical part of this investigation is undoubtedly rigidly exact under the specified simple conditions.

It is suggested that critics who endeavor to tear down and destroy the work of others by hastily made and unsubstantiated assertions, which may prove later to have been unwarranted or incorrect, might do some thing which is really of value, by devoting their efforts to improvements and further developments instead of to mere destruction. Before tearing down a structure built by others, one should be very sure first that it is a dangerous one; if one thinks he can build a better one, then let both stand; the fittest will survive in the end without the need of the hand of the destroyer.

As to the usual crop of claimants of priority after something has been disclosed, the practice of secreting information of benefit to fellow engineers, until someone else has taken the trouble to publish it, and then of claiming priority and expecting recognition, is not in accordance with a high standard of professional ethics, and is believed to be more apt to discredit the claimant than to do him credit. Unpublished ideas are of no benefit to the profession at large; it is the one who takes the trouble to publish them, that aids his colleagues.

NOTE

The following paper is to be read at the 245th meeting of the American Institute of Electrical Engineers in **New York, March 11, 1910.** This paper is to be presented under the auspices of the Industrial Power Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **D. B. Rushmore, Chairman Industrial Power Committee, Care A.I.E.E., 33 West 39th Street, New York,** so that they will be received not later than March 10, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

A paper to be presented at the 245th meeting of the American Institute of Electrical Engineers, New York, March 11, 1910.

(Subject to final revision for the Transactions.)

LARGE ELECTRIC HOISTING PLANTS

BY WILFRED SYKES

The development of large electrically-driven hoisting plants has gone on simultaneously with that of balancing systems designed to equalize the input, thus relieving the generating stations of excessive peak loads. It will be readily understood that success from a commercial standpoint could hardly be hoped for with large plants requiring a maximum of 2000 or 3000 horse power unless the average load had some reasonable relation to the maximum, excepting, of course, those cases where the generating stations were of such capacity that the peak loads did not interfere with the operation or regulation of the plant generally. Such cases are, however, seldom met with, a notable instance being the mines at Johannesburg, which are to be supplied with power by the Victoria Falls Co. There it is intended to use three-phase motors up to 2000 h.p. maximum for hoisting, but owing to the large amount of power required for other purposes, the peak loads due to these motors will not materially affect the generating stations, which will have a capacity of about 100,000 kw. In the majority of cases where electric hoists are used the mines have either their own generating plants or purchase power under such conditions that the cost is materially affected by the load factor, and for economical working it is essential that the average load should be as high as possible. When a mine generates its own power it will usually be found that the proportion of the hoisting load to the rest of the requirements is very large, especially with deep mines, and the peak loads necessitate special provision being made to prevent them from interfering with the operation of the other part of the plant. The success of electric hoisting plants in

Europe when motors up to 3500 h.p. have been used, superseding steam hoists, has demonstrated that by carefully studying the subject there is no difficulty in securing very satisfactory results, not only from an operating, but also from a commercial standpoint. When considering large hoisting plants with the idea of driving them electrically it is essential that the load characteristics should be carefully studied, to determine not only the correct size of the machine, but also the system to be adopted. With steam-driven hoists this is not absolutely essential, for since the worst conditions are provided for, they cannot very well be overloaded; but as the output of electric motors is usually limited by the heating, rather than by the maximum safe load, the output at all points of the hoisting period must be known in order to design intelligently the electrical part of the equipment, including also any equalizing system which may be adopted. In this paper it is proposed to describe briefly some methods used by the author for the determination of load diagrams and also the characteristics of balancing systems and their economy.

Cylindrical drum hoists. This is the most common type of hoist and the load diagram is very simply obtained. Dealing first with a single-drum hoist, with one cage without any counter balance, the static moment at the beginning of the trip will be,

$$M = (W+Rl+C)\,r+F+A$$

when M = total moment or torque in ft. lb.
R = weight of rope per ft.
l = depth of shaft in ft.
C = weight of cage in lb. (including cars).
r = radius of drum in ft.
F = total friction expressed in ft. lb.
A = accelerating moment in ft. lb.
W = weight of load to be hoisted.

As the cage is hoisted, rope will be wound on the drum and the load will be correspondingly reduced. With electrically-driven hoists the rate of acceleration is usually constant so that the distance traveled during this period will be

$$S\,t \div 2$$

when S = full speed of hoist in ft. per second.
t = time of acceleration.

Therefore, at the end of the accelerating period the load will be,

$$M_1 = \left(W+C+Rl-\frac{S\,t\times R}{2}\right) r+F+A$$

The hoist having reached full speed the accelerating moment drops out giving,

$$M_2=\left(W+C+Rl-\frac{S\,t\times R}{2}\right) r+F$$

During the full speed period the load will be uniformly reduced by the rope wound on the drum until at the end of this period there remains only the amount of rope corresponding to the distance traveled during retardation, or,

$$M_3 = \left(W+C+\frac{S\,t_2\,R}{2}\right) r+F$$

when t_2 = time of retardation.
To bring the load to rest the energy stored in the moving parts must be absorbed either in lifting the load or by the brakes. At the beginning of retardation the load is therefore,

$$M_4 = \left(W+C+\frac{S\,t_2\,R}{2}\right) r+F-V$$

when V = retarding moment.
At the end of the trip the load will be,

$$M_5 = (W+C)\,r+F-V$$

Considering the case of a double-drum hoist, the conditions are somewhat different as the cages balance one another. At starting we have

$$M = (W+Rl)\,r+F+A$$

During acceleration the weight on the loaded side will be reduced by that of the rope wound on the drum, but from the second drum a corresponding length of rope will be unwound

so that the effective load will be reduced by twice the weight of the rope wound on the drum, or,

$$M_1 = (W + R\,l - S\,t \times R)\,r + F + A$$

At the beginning of the full speed period the load is as above except that there is no accelerating moment. The load continues to decrease as the rope is wound on one drum and off the other, until at the end of the full speed run we have,

$$M_3 = (W - R\,l + S\,t_2\,R)\,r + F$$

At the beginning of retardation the load is

$$M_4 = (W - R\,l + S\,t_2\,R)\,r + F - V$$

and at the end of the trip,

$$M_5 = (W - R\,l)\,r + F - V$$

In order to work out the load diagram as above, it is of course necessary to have such data as weight of load, rope, cages, etc., but on the question of time and speed, acceleration and friction, a few remarks may not be out of place.

Time. As usually presented, the problem is to obtain a certain maximum output per hour, usually a good deal more than the average, so as to allow for delays. A certain time will be required for changing the cars and after deducting this from the time per trip, the actual hoisting time is obtained. This of course applies to balanced hoisting and, with a single cage, time must be allowed for lowering. If we suppose that our experience indicates that a certain period, $t + t_2$ will be reasonable for acceleration and retardation, the full hoisting speed will be,

$$S = \frac{l}{T - \frac{t + t_2}{2}}$$

when T = actual hoisting time; or supposing that the full speed is given, the time available for acceleration and retardation is

$$2\left(T - \frac{l}{S}\right)$$

Acceleration and retardation. The accelerating moment will depend upon the total mass of the moving parts and the velocity. It will generally be found convenient to reduce all the moments of inertia to the drum radius. The total will be made up of the load, cages, ropes, sheaves, drums, gearing and motor, the first three of which can be readily determined. The inertia of the sheaves will depend on the design, but if data are not available we may approximate by taking $\frac{W r_1^2}{g} = 25\, r_s^2$ for each sheave; when r_s = radius of sheave, and for each of the drums $100\, r^2\, W'$ when W' = width of drum. These are of course only rough guides and the actual figures should be obtained if possible. If the weights are known it is safe to take the radius of gyration, or $r_1 = 0.8r$, in calculating the inertia. The gearing, if any, must be worked out from the weights and dimensions and the motor data can only be obtained by making a rough estimate of the size and picking out a suitable machine. The total amount of inertia I_1, reduced to the drum will be therefore,

Traveling parts $\qquad \dfrac{(W + 2\,l\,R + 2C)\, r^2}{32}$

Sheave $25\, r_s^2 \times \left(\dfrac{r_s}{r}\right)^2$

Drum $100\, r^2\, W'$

Gearing $\dfrac{W r_1^2}{g} \times \left(\dfrac{O_1}{O}\right)^2 + \dfrac{W r_1^2}{g} \times \left(\dfrac{O_2}{O}\right)^2$ etc.

Motor $\dfrac{W r_1^2}{g} \times \left(\dfrac{M_s}{O}\right)^2$

When r_s = radius of sheave in ft.

O = speed of drums in rev. per min.

$O_1\, O_2$ = speed of the different parts of the gearing, O_1, being main gear $= O$, O_2 = countershaft speed and so on, each part of the gearing being worked out separately, M_s = motor speed.

The angular velocity of the drum is,

$$\omega = \frac{2\,\pi\, N}{60}$$

when N = rev. per min.

The accelerating moment is

$$A = \frac{I_1 \omega}{t}$$

and the retarding moment

$$V = \frac{I_1 \omega}{t_2}$$

Friction. The friction is very difficult to determine, as it varies with the condition of the shaft, cages, sheaves, hoist and speed. For moderate speeds the friction may be taken for a direct-coupled hoist as being equal to an extra load of from 5 per cent to 7½ per cent of the total suspended weight, including ropes, cages and load, and with a geared hoist, from 7½ per cent to 10 per cent, but this is only a rough guide and it is necessary to depend on experience more than anything else. Instead of calculating the static moment of the load at various points a very simple graphic method may be used. Referring to Fig. 1 draw $c\,d$ and $e\,f$ at right angles to $a\,b$, the distance between them being equal l/S, and on $c\,d$ lay off to a suitable scale the value corresponding to F, drawing $g\,h$ parallel to $a\,b$, and above this, fix the point $x = (W + Rl)\ r$, and also on $e\,f$ set off the value $y = (W - Rl)\ r$. On either side of $c\,d$ and $e\,f$ draw the verticals $j\,k$ and $l\,m$ and $n\,o$ and $p\,q$ at a distance representing half the period of acceleration and retardation respectively. Connect $x\,y$ and draw the horizontals $x\,w$ and $y\,v$. From the point where $x\,y$ intercepts $l\,m$ and $n\,o$, draw $x'w$ and $y_1\,v$. On $j\,w$ from w set off the value corresponding to the accelerating moment w_1 and draw parallel to $w\,x'$, $w_1\,x_2$ and on $v\,q$ from v the retarding moment v_1 drawing parallel to $y_1\,v$, $y_2\,v_1$. The complete torque diagram is the area $k\,w_1\,x_2\,x'\,y_1\,y_2\,v_1\,q$ and the total running line is shown by $k\,q$. To convert the values in ft.-lb. to horse power we must multiply by the angular velocity ω and divide by 550. For practical purposes we may consider that the current taken by the motor will be proportional to the torque and, as the heating depends upon the current, the torque diagram must be taken as the basis for calculating the capacity of the machine required. The usual method is to assume that the heating varies as the square of the current and that the heat is carried away

from the motor at a constant rate. On this basis the size of the motor would be,

$$H\,P=\sqrt{\frac{\frac{H\,P_1^2+H\,P_2^2}{2}\times t+\frac{H\,P_3^2+H\,P_4^2}{2}\times t_1+\frac{H\,P_5^2+H\,P_6^2}{2}\times t_2}{T_1}}\,.$$

when $H\,P_1$ $H\,P_2$ $H\,P_3$ $H\,P_4$ $H\,P_5$ and $H\,P_6$ correspond to the values at w_1 x_2 x' y_1 y_2 and v_1 respectively,

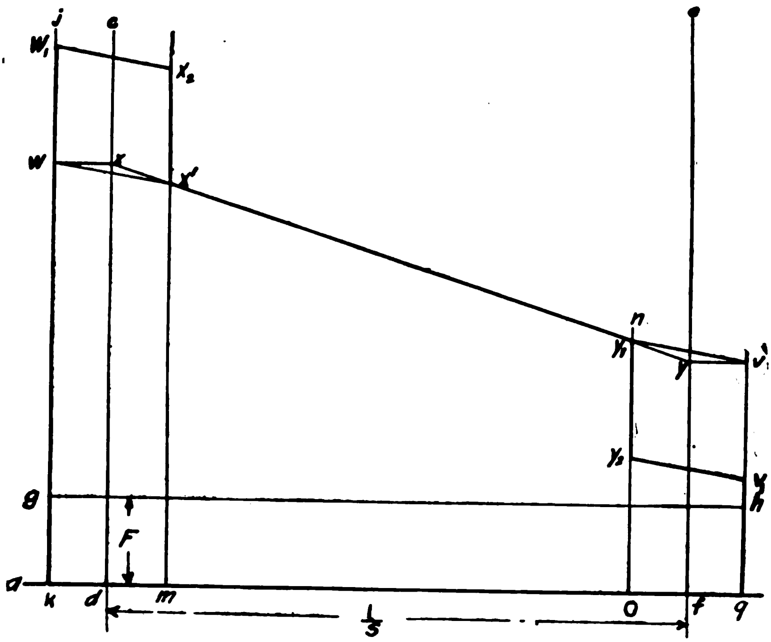


Fig. 1

t, t_1 and t_2 = time of acceleration, constant speed and retardation respectively,

T_1 = total time for each trip, including the period of rest.

This assumption is not altogether true for with induction motors there are extra losses in the rotor at starting, and with direct current machines the reverse is the case. The total losses do not increase exactly as the square of the current, nor is the heat carried away at the same rate all the time, but this gives a guide to the size of the motor required and if a proper allowance

is made for these inaccuracies, the proper size of machine can be fixed very closely.

Whiting and Koepe hoists. These hoists are used to some extent, the latter very largely in Germany, and as a tail rope is generally used with the former, and always with the latter, they may be taken together. By using a tail rope of the same weight as the hoisting rope, the load to be hoisted becomes the only unbalanced part of the whole system and the diagram is very easily obtained. At the beginning of the trip the total load is

$$M = W\,r + F + A$$

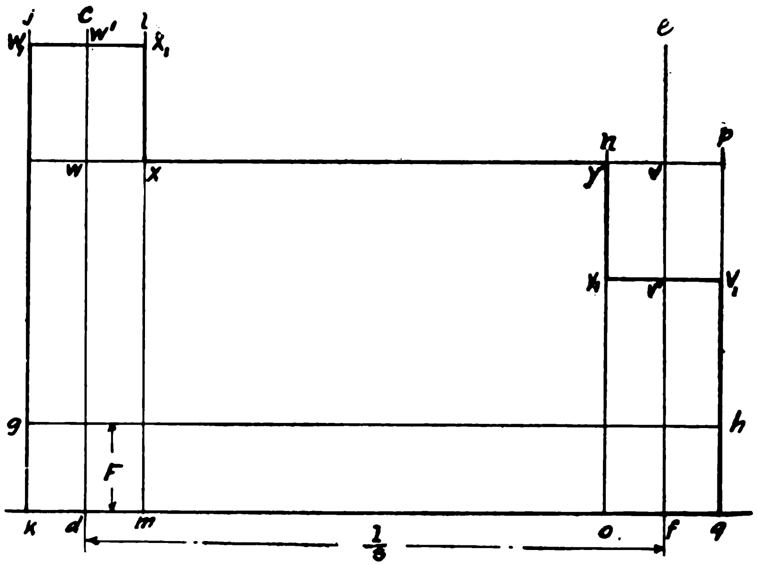


FIG. 2

At the end of the acceleration the only difference is that the accelerating moment disappears leaving

$$M_2 = W\,r + F$$

During retardation we have

$$M_5 = W\,r + F - V$$

The diagram may be readily obtained graphically as before. Referring to Fig. 2, set off $d\,f$ equal to l/S and draw $c\,d$ and $e\,f$.

Parallel to *a b*, plot *g h* representing the friction, and above the *w v* equal to *W r*. Draw *j k*, *l m* and *n o*, *p q* as before, the distance between them and *c d* and *e f* being equal to half the time for acceleration and retardation respectively. From *w* set off *w'* corresponding to the accelerating moment drawing w_1 x_1 parallel to *w x*. From *v* set off *v'* corresponding to the retarding moment. drawing y_1 v_1 parallel to *y v*. The area *k* w_1 x_1 *x y* y_1 v_1 *q* represents the torque diagram for the motor which should be treated as before in order to determine the size of the motor. In connection with Koepe pulleys, and also to some extent with Whiting hoists, it is necessary to determine the factor of safety against the rope slipping. On one side the maximum pull on the rope is made up of cage, load, rope weight, acceleration of these parts and of one sheave. On the other side there is rope weight, and cage minus the acceleration of these parts and of one sheave. Reducing the weights of the sheaves to the pulley radius the accelerating pull will be

$$\frac{(W+C+R\,l+S')\,a}{32}$$

when a = acceleration in ft. per sec.

S' = weight of sheave reduced to pulley radius.

On the other side it is

$$\frac{(C+R\,l+S')\,a}{32}$$

In order to cause slipping the greater pull must exceed the smaller one multiplied by $e^{\alpha\mu}$ when

e = base of nat. log. 2.7182.

α = angle of contact of rope on sheave in radius.

μ = coefficient of friction between rope on pulley = 0.18.

Usually the angle of contact is about 190 degrees so that for the rope to slip we must have

$$\left\{ W+Rl+C+\frac{(W+R\,l+C+S')\,a}{32} \right\}$$

$$> 1.82 \left\{ Rl+C-\frac{(R\,l+C+S')\,a}{32} \right\}$$

With Whiting hoists the angle of contact is 180 degrees and the multiplying factor is, 1.75×number of wraps around driving sheaves.

Conical drum hoists. The determination of the load diagram for this type of hoist is somewhat more complicated than that for the hoists already dealt with. The object of conical drums is to compensate for the unbalanced load due to the rope, and to do this completely the following conditions must be met

$$r\,(W+Rl+C)-r_1\,C=r_1\,(W+C)-r\,(C+Rl)$$

when r = minimum radius.
r_1 = maximum radius.

This gives the proper dimensions for the beginning and end of the trip, but at intermediate points there are slight unbalanced loads if a plain conical drum is used. The variation from the ideal condition, however, is unimportant. From the smaller radius the greater can be obtained as follows:

$$r_1=r\left(1+\frac{2\,Rl}{2C+W}\right)$$

The length of the surface of the drum will be

$$L=\frac{l\times d}{\pi\,(r+r_1)}$$

when d = space required for each turn of the rope.

In order to obtain the same output as with a cylindrical drum the maximum speed will be approximately in the ratio of

$$\frac{r+r_1}{2}:r_1$$

which gives a value a little too high, as the rope is not at the maximum radius when retardation begins, but it is, however, near enough when making preliminary calculations in order to determine what average speed can be assumed. It will be found more convenient when dealing with this type of hoist to calculate the distance traveled in terms of revolutions of the

drums instead of in feet. Supposing that a certain maximum speed S_{max} is fixed by considerations such as shaft construction, etc., the mean speed S_m will be

$$S_m = \frac{S_{max} \dfrac{r + r_1}{2}}{r_1}$$

which, expressed in revolutions per second, is

$$\text{Rev. per sec.} = \frac{\dfrac{S_{max} \dfrac{r + r_1}{2}}{r_1}}{2\pi\, 60 \dfrac{r + r_1}{2}} = \frac{\dfrac{S_{max}}{r_1}}{2\pi\, 60}$$

The total number of revolutions to be made per trip is

$$\text{Rev. per trip} = \frac{l}{2\pi \dfrac{r + r_1}{2}}$$

The time available for acceleration and retardation is therefore:

$$t + t_2 = 2 \left\{ T - \frac{\dfrac{l}{2\pi \dfrac{r + r_1}{2}}}{\dfrac{\dfrac{S_{max}}{r_1}}{2\pi\, 60}} \right\} = 2 \left\{ T - \frac{\dfrac{2\,l}{r + r_1}}{\dfrac{S_{max}}{60\, r_1}} \right\}$$

$$= 2 \left\{ T - \frac{120\, l\, r}{S_{max}\,(r + r_1)} \right\}.$$

The speed in rev. per sec. being known, the revolutions can be readily found. The distance traveled during acceleration will be

$$l_1 = 2\pi \left(r + \frac{i\,z}{2} \right) z$$

i = increase in radius per turn $= r_1 - r \div$ rev. per trip
z = revolutions during acceleration.
z^1 = revolutions during retardation.

During retardation the distance traveled will be

$$l_2 = 2\pi \left(r_1 - \frac{i\,z^1}{2}\right) z^1$$

The inertia of conical drums may be taken as approximately, $200\,W' \frac{r^2 + r_1^2}{2}$ if the weight is not known.

Static moment. The variation of the static moment may be easily followed if the drum is considered as being extended so as to complete the cone with the apex at a Fig. 3. The area of the cone will be proportional to the square of the radius O, and as the weight of the rope on the drum will be proportional to the area covered, assuming an even spacing between the turns, it will be seen that it will also vary as the square of the distance from a. The length of the completing cone l' will be

$$l' = \frac{l \times r}{r_1 - r}$$

The number of turns of rope on this part will be

$\frac{l'}{d}$ when d = space taken by each turn of rope in ft.

and the length of rope $= \pi r \frac{l}{d}$

If the total weight of the rope on the drum and completing cone is considered as a separate load, none being wound on the drum, the static moment would vary with the distance from a, being $R\,L' \times$ radius. The amount of rope wound on the drum, however, varies with the square of the distance from a and the equivalent static moment as the cube; consequently the actual static moment for any point will be,

$$M_r = R\,L'\,r_2 - R\,L'\,r_1 \left(\frac{r_2}{r_1}\right)^3$$

when M_r = static moment of rope.

R = weight of rope in lb. per ft.

L' = total length of rope wound on drum and completing cone.

r_2 = any radius.

r_1 = maximum radius of drum.

From the above it is very easy to determine the static moment diagram by plotting a few points and drawing a curve through them; or graphic methods may be used.

Referring to Fig. 3, set off on $a\,b$ from a, the distance $a\,b'$ corresponding to the number of turns of rope on the drum and completing cone. Parallel to $a\,b$ draw $a_1\,b_1$, the distance between them being equal to $(L\,R + W + C)\,r_1$ and from b' drop the vertical $b'\,b_1'$. From the point a' corresponding to the smaller end of the drum, drop the vertical $a'\,a_1'$. A straight line from a to b_1'. would represent the static moment if none of the rope were wound on the drum, but, as pointed out, this value must be decreased by a certain amount, varying as the cube of the distance from a. On $b'\,b_1'$ lay off the value $L\,R\,r_1$ to Z leaving $z\,b_1'$ representing the actual static moment at the end of the trip and connect $a\,z$. If a cubic parabola is drawn between a and z, the distance between it and $a\,z$ will be the static moment diagram for the rope, and between the curve and $a\,b_1'$ the static moment diagram for the loaded side of the hoist. This may be done by a simple graphical method. Divide $a'\,b'$ into any number of parts and draw the verticals 2, 3, 4, etc. from $a\,b$ to $a_1\,b_1$. From the points of intersection with $a\,z$ draw the horizontals I, II, III, etc. to $b'\,b_1'$ and with $b'\,z$ as a diameter draw the semicircle. With b' as a centre describe the arcs $I\,I'\;II\,II'\;III\,III'$, etc., and from the intersections with the semicircle draw horizontals to $b'\,b_1'$ and from these .points vectors to a. The intersection of I' and $a'\,a'_1$, II' and 2, III' and 3, etc., are points on the cubic parabola. This arrangement gives the diagram on the base $a\,b_1'$ but we can obtain it on $a_1\,b_1$ if, instead of drawing the vectors to a, they are drawn to a_1. The static moment for the unloaded side can be obtained in the same way. On $a'\,a_1'$ from a_1', lay off p corresponding to the static moment of the cage or $C\,r$ and draw $p\,z$. Parallel to $p\,z$ draw $I'\,I_1$, $II'\,II_1$, etc., and from the intersections with $a'\,a_1'$ the vectors to b_1, the distance of which from b_1' corresponds to the number of turns on the completing cone. The intersection of $I_1\,b_1$ with $b'\,b_1'$,$II_1\,b_1$ with 2, $III_1\,b_1$ with 3, etc., are points on the static moment diagram for the unloaded side. The distance between the two curves thus obtained is the resultant static moment for the hoist. In Fig. 3 a case has been taken where the static moment at the end of the trip is the same as at the beginning, the radii being obtained as already shown, and it will be noticed that the resultant moment is not quite a straight line, but the deviation is so small that it can

be neglected. It will therefore be seen that if the condition for the complete compensation of the rope weight is met by properly proportioning the radii of the drum the static moment during the whole period may be taken as

$$M = (W+C)\,r - C\,r = W\,r$$

Inertia. It will be found convenient to reduce the inertia of the sheaves to the drum radius, assuming that it varies instead of the speed, which of course gives the same result. The equivalent

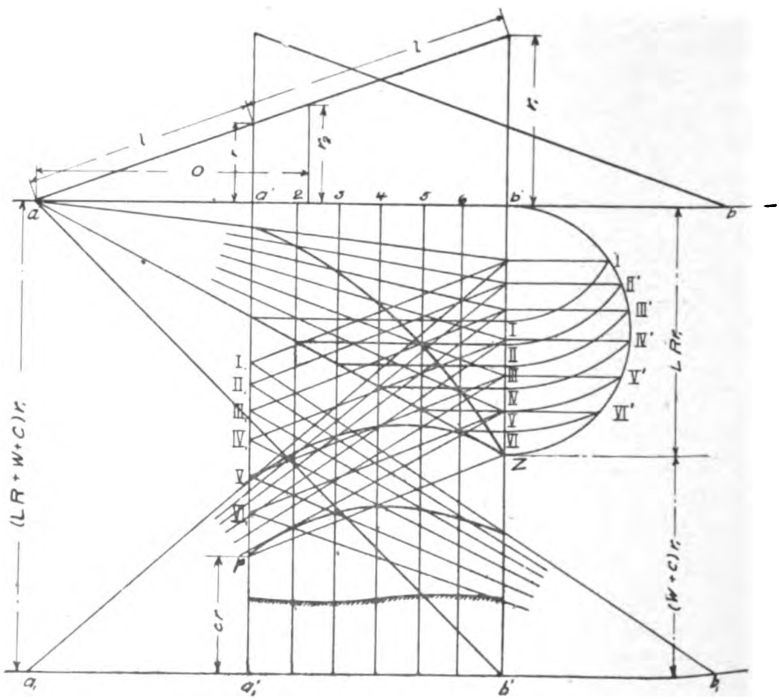


FIG. 3

inertia will therefore vary with the square of the drum radius, being a maximum at the larger radius when it is equal to

$$I_s \frac{r_s^2}{r_1^2}$$

in which I_s = inertia of sheave, and
r_s = radius of sheave.

If a simple parabolic curve is drawn from a point b' corresponding to the apex of the cone, Fig. 4 to the end of the drum on the line $b' b_1'$ the maximum value corresponding to $I_s \frac{r_s^2}{r_1^2}$, the part between the smaller and greater radii, $a_2\, b_2$ corresponds to inertia of one sheave. By drawing a similar curve for the second sheave from b_1', $a_3\, b_3$ will correspond to the inertia of the second drum and by adding the two the combined inertia curve $a_4\, b_4$ may be obtained. It will be seen that this curve varies

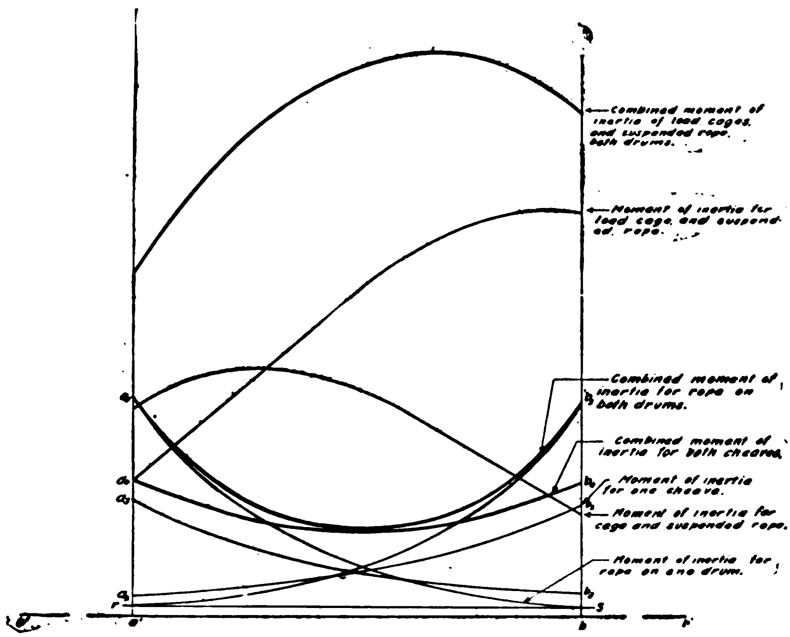


FIG. 4

very little from a straight line and for practical purposes the total inertia of the sheaves may be taken as constant at

$$I_{st} = I_s \frac{r_s^2}{r^2} + I_s \frac{r_s^2}{r_1^2}$$

The inertia of the load and suspended rope may be obtained from the static moment diagram. As the moment of inertia is $\frac{W\, r^2}{g}$, if the static moment or $W\, r$ is multiplied by $\frac{r}{g}$

the various values are found, and by taking a few points and multiplying by the corresponding radius and dividing by 32, a curve is easily obtained.

The same must be done for the unloaded side, and the two curves which are thus obtained are combined. The form of these curves is shown in Fig. 4 and it will be found that for practical purposes no great inaccuracy will be introduced if the inertia is taken as the average of the two.

$$I_L = \frac{\left\{(W + C + Rl)\, r^2 + C r_1^2\right\} + \left\{(W + C)\, r_1^2 + (C + Rl)\, r^2\right\}}{2g}$$

In the above the suspended rope has been allowed for but the rope on the drum must also be considered. It has been seen that the amount of rope on the drum will vary as the square of the radius and as the inertia of any mass also varies at the same rate the inertia of that part of the rope on the drum will vary r^4. By drawing a fourth degree parabola from the apex of the cone b' to the point on b_5, Fig. 4, corresponding to the value

$$I_R = \frac{R l r_1^2}{2g}$$

the inertia of one rope will be obtained and a similar curve from b_1' to a_5, will give the value for the second rope. By drawing a horizontal rs from the points of intersection with a' and b the inertia of the part on the completing cone is subtracted, that above the base rs representing that on the drums. By combining the curves thus obtained the total inertia of the rope on the drums will be obtained. As this curve does not vary very much from a straight line and the total value is small, it is sufficient for practical purposes to consider the inertia of this part of the total as being constant at

$$I_{Rd} = \frac{Rl \dfrac{r^2 + r_1^2}{2}}{g}$$

The inertia for all parts having been found, the load diagram may be determined in the same way as with cylindrical drum hoists.

Reel hoists. The reel hoist may be considered as a conical drum, the radius of which increases at each turn by an amount equal to the thickness of the rope. In order to compensate completely for the weight of the rope, the inner and outer radii must be determined in the same way as with a conical drum, the ratio being

$$r_1 = r\left(1+\frac{2\,R\,l}{2\,C+W}\right).$$

The increment by which the radius is increased being fixed by the rope thickness, it will be seen that the inner and outer radii must be such that with the full amount of rope on the reel the proper ratio is obtained. This ratio being fixed, it is obvious that there is only one value for the inner radius which will give the correct value for the outer radius with a certain rope thickness. The space occupied by the rope with a full reel is

$$Q = \pi\, r_1^2 - \pi\, r^2$$

and if the radii are taken in inches the length of the rope in feet will be

$$l = \frac{\pi\, r_1^2 - \pi\, r^2}{12\,d}$$

when d = thickness of rope in inches.

Taking $x = \frac{r_1}{r}$ we obtain,

$$\pi\,(x\,r)^2 - \pi\, r^2 = 12\,l\,d$$

$$\pi\,(x^2-1)\,r^2 = 12\,l\,d$$

$$r = \sqrt{\frac{12\,l\,d}{\pi\,(x^2-1)}}.$$

It may be that the value for r thus found will be too small for the size of the rope taken, the bending stresses being too high, and in this case it will be necessary to reduce the thickness and increase the width, but the permissible variation in this direction is comparatively small since only a few thicknesses are manufactured commercially. When the depth exceeds 1500 to 2000 ft. it will be found practically impossible to secure a complete compensation for the rope weight because the inner radius is so

small that a suitable rope is not obtainable. Having fixed the radii, the load diagram may be determined in the same manner as that of a conical drum hoist.

Balancing systems. Practically all balancing systems utilize a fly-wheel, the speed of which is varied so that it gives up or absorbs energy according to the demands of the system. A storage battery may also be used for the same purpose and under certain circumstances it may be more economical than a fly-wheel, as the losses with the latter are constant and independent of the load, while the storage battery losses only occur when the battery is being used.

The main requirements of a balancing system are that it should be capable of preventing the peaks from coming on generating stations, it should be automatic in action, and the losses connected with it should be as low as possible.

The first practical system to be introduced was that proposed by Mr. Carl Ilgner, which, in various modified forms, has been very widely adopted for all classes of heavy work where greatly fluctuating loads have been taken care of. The Ilgner system as arranged for use with an alternating current source of supply consists of an alternating current induction motor with a wound rotor, coupled to a direct current generator, which, in turn, feeds a direct current shunt-wound hoist motor. Coupled to the motor generator is a suitable fly-wheel designed to take care of the peak loads. The fields of the hoist motor and of the direct current generator are excited separately by a small exciter coupled to the motor generator set, means being provided for automatically maintaining its voltage constant when the speed of the set varies. The speed of the motor generator set is controlled by means of an automatic slip regulator operated by the line current. The scheme of operation is as follows:

At the beginning of a hoist cycle the fly-wheel will be running at full speed, all resistance being cut out of the motor rotor. In order to start the hoist, the generator will be gradually excited in the proper way to obtain the desired direction of rotation. As the speed of the hoist motor with constant field excitation will be practically proportional to the voltage of the generator, when the latter is increased the speed of the hoist will also increase until with full voltage the maximum speed is obtained. The only rheostatic losses at starting are those in the regulator controlling the generator field, which are negligible.

When the load on the induction motor exceeds the mean value

for which the slip regulator is set, resistance is automatically introduced into the rotor so as to cause a reduction of speed, thus enabling the flywheel to give out a portion of energy stored in it and thereby assisting the motor to drive the generator. The speed will be automatically reduced so as to maintain constant input to the three-phase motor until the fly-wheel has given out all the energy required in excess of the mean value. When the load falls below this mean value the regulator will cut out the resistance in the rotor causing the set to increase in speed, thus storing energy in the flywheel and keeping the demand on the line constant.

The use of resistance in the rotor of the three-phase motor introduces a certain loss which will average half the slip between full and minimum speeds, but, as a rule, this loss is comparatively small compared with the output of the plant.

The question as to the most economical value to adopt is a very complicated one, depending as it does upon the first cost of the flywheel, the running losses, the time the plant is in service, etc. It will be seen that should the plant run for considerable periods without load it might be advisable to allow a fairly large slip and to use a light fly wheel so that the constant loss would be small. On the other hand, if the plant runs continuously, the intervals between trips being short, the slip regulator losses will bear a totally different relation to the input, and under such circumstances a relatively small slip and a heavy flywheel might be the most economical arrangement. It has been found in practice that a slip of 12 per cent to 15 per cent is about the most economical value, although in some plants a slip up to 20 per cent is provided for. Since the energy stored in the flywheel is proportional to the square of the velocity, it will be seen that by increasing the slip a proportional increase is not obtained in the output. Thus with a 15 per cent slip the energy available will be 28 per cent of the total stored in the flywheel. With 20 per cent slip the amount available is only increased to 36 per cent.

The Ilgner, or motor generator arrangement, is the most important of all equalizing systems, probably 90 per cent of the plants installed being designed on this principle. It will be noted that the whole of the power used by the hoist is transformed and also that there are no rheostatic losses at starting.

Fig. 5 shows the general connections of a hoisting plant on the Ilgner system with alternating current supply and from the

description given the functions of the various parts will be easily followed.

Another system of importance, suitable for alternating current, which has a quite large field of application, is that known as the converter system, the principle of which is altogether different from that of the Ilgner system.

Fig. 6 shows the connections of this system as applied to three-phase hoisting plants. The hoist motor in this case is of the three-phase induction type with a wound rotor, being started by means of a rheostat. In order to equalize the demand on the

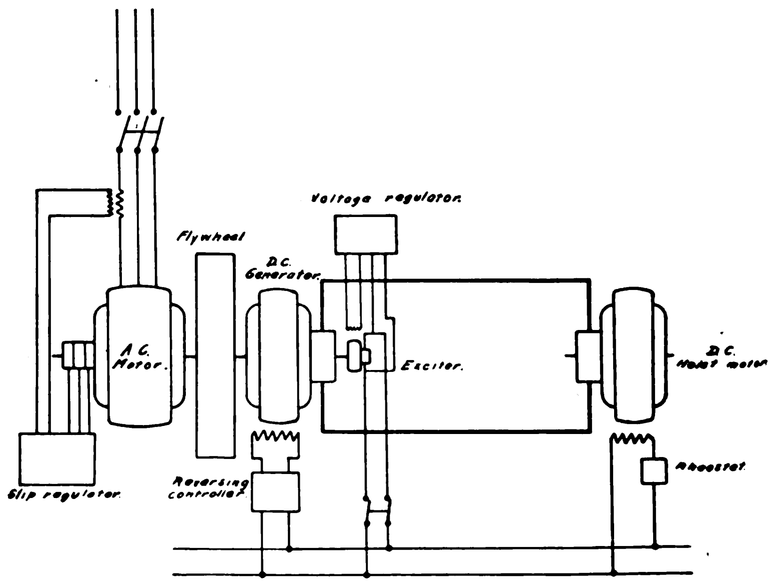


FIG. 5

line, the equalizing system is connected in parallel with the generator station. It consists of a rotary converter and a direct current machine to which is coupled a suitable fly wheel. The operation of the arrangement is as follows:

The rotary converter acts only as a connecting link between the alternating current system and the equalizing set, which consists of a shunt-wound direct-current machine and the fly wheel. The field of this machine is controlled by a regulator, operated by the main line current. At the beginning of a trip the fly wheel is running at full speed, and when the load exceeds

the mean value, the regulator automatically strengthens the field of the equalizing machine so that it acts as a generator driven by the fly wheel. The amount of energy given to the line will depend on the requirements in excess of the mean, as the regulator will continue to cut out resistance so long as there is any tendency for the line current to increase above the mean.

When the demand drops below the average the regulator will weaken the field, causing the machine to run as a motor, which taking energy from the line, speeds up the fly wheel, the rate at which resistance is introduced to the field depending on the difference between the demand on the line and the mean load. In this way energy is stored in the fly wheel and the line load is kept constant. The rotary converter changes either direct current

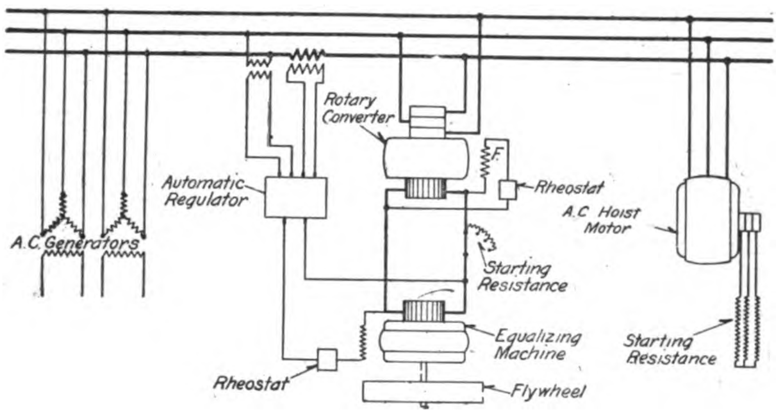


FIG. 6

to alternating current or vice versa, depending on whether the fly wheel set is giving up or absorbing energy. It will be seen that the speed variation is obtained by field regulation, so that the loss is negligible, whereas with the Ilgner system it is from 7½ per cent to 10 per cent of the input to the driving motor. This is a very important feature in equalizing systems with direct current machines, as a much greater slip can be economically obtained, it being the usual practice to allow from 20 per cent to 25 per cent, and consequently the fly wheels can be comparatively light. The machines of the equalizing set need only be large enough to deal with the loads which exceed the mean value, and under ordinary circumstances the capacity will not be more than about half that of a motor generator set for the same

duty. The equalizing equipment is quite independent of the hoisting motor, so that it may be out of service and the only difference will be that the peak loads will come on the line, but with the Ilgner system the hoist is dependent upon the motor generator.

The main difference between the two systems is that the Ilgner method provides for starting the hoist motor by voltage control without any rheostatic losses, while the converter arrangement makes no provision for doing so. When considering the economy of both systems this difference must be considered, as starting losses are often a large proportion of the total input. The question of starting is one of the most important ones with large hoists, and on this account the Ilgner system is preferred for heavy work. Motor generator sets without fly wheels have been installed in a number of instances for the sole purpose of obtaining a simple and efficient method of starting. With small hoists the starting devices are not difficult to design and this feature, together with the fact that one converter equalizing equipment may be used for a number of hoists, gives this arrangement an advantage over the Ilgner system, especially as the cost is somewhat lower. It will be seen that the converter equalizing equipment is not necessarily located near the hoist, which is an important feature when it is inside a mine. In this case a high tension system may be used, transformers being placed between the converter and the line, and the equalizing set being in the power station or substation on the surface.

When the power supply is direct current the speed of the driving motor of the motor generator set is varied by shunt regulation and the slip may be made between 20 per cent and 25 per cent. With the other arrangement the converter is omitted, the equalizing machine being connected directly across the line. This latter arrangement is very simple, and so long as the starting of the motors can be done rheostatically, it appears to be the most reasonable system to use. A number of variations of the above arrangements have been employed but the principles are the same. There is another arrangement which under certain circumstances has some value. Its main feature is a reversible booster set, the voltage of which is the same as the line voltage. The general arrangement is shown in Fig. 7, from which it will be seen that the starting of the hoist motor is arranged for by regulating the booster field. When the hoist is at rest the booster has full field, both the booster and the motor running as motors

off the line, a small current always passing through the hoist motor. When the hoist is started the booster field is weakened, the back e.m.f. being reduced, and a current flows through the hoist motor sufficient to start it. The difference between the input of the hoist and the load on the line corresponding to the current taken, is used by the booster, running as a motor, to drive the motor as a generator, thus returning power to the line. The field of the booster is gradually reduced until it is zero, when the line voltage will be applied directly to the hoist motor. The field is now reversed and the booster voltage is added to that of the line until with full excitation the pressure across the hoist

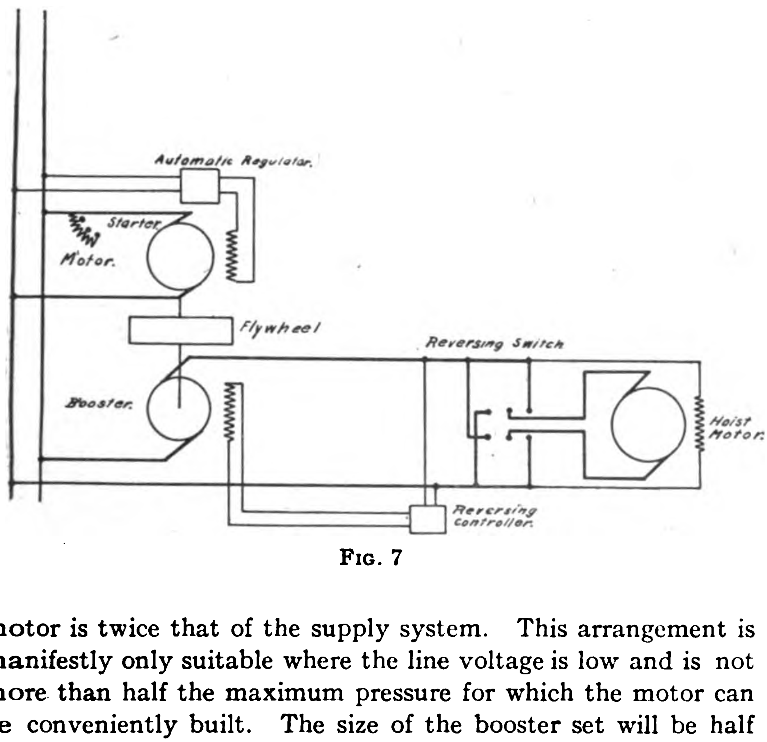


FIG. 7

motor is twice that of the supply system. This arrangement is manifestly only suitable where the line voltage is low and is not more than half the maximum pressure for which the motor can be conveniently built. The size of the booster set will be half the total input to the hoist motor. By adding a fly wheel to the set and by providing for automatic regulation of the motor field the line load may be equalized. In the case of large plants, two hoist motors may be used connected in series and a supply voltage of 500 to 600 volts may be adopted, giving 1000 to 1200 volts at the motors.

Characteristics of balancing systems. The load diagram for the

hoist motor having been determined as already described, it is used as a basis for the calculation of the dimensions of the fly wheel and the output of the various machines required according to the systems adopted. Dealing first with general principles, it will be noted that the energy in any moving body is

$$E = \frac{W V^2}{2 g}$$

when E = energy in ft. lb. per sec., from which it will be obvious that for any variation of speed the energy given up or absorbed will be proportional to the square of the minimum and maximum velocities, or,

$$E = \frac{W (V^2 - V_1^2)}{2 g}$$

when V = maximum velocity in ft. per sec.
V_1 = minimum velocity in ft. per sec.

In the case of a revolving wheel the velocity taken is that at the radius of gyration or the point at which, if all the weight could be concentrated, would give the same effect as when distributed throughout the wheel. This radius is proportional to the square of the distance of the various masses from the center and for a flat circular disk of radius r it is

$$\text{Radius of gyration} = \sqrt{\frac{r^2}{2}} = 0.707\, r$$

With wheels of irregular section the radius of gyration will depend upon the distribution of the weight. It will be obvious that the higher the velocity the greater will be the amount of energy available for a given change of speed, and therefore for a certain output the weight will be reduced as the square of the increase in velocity. For this reason balancing systems are provided with fly wheels running at a high peripheral velocity, the limit being fixed by the class of material used. In Europe cast steel has been almost exclusively used, one or two steel manufacturers having made a specialty of this type of casting

to withstand the stresses due to centrifugal force. Small cast steel wheels have been built for peripheral speeds up to about 23,000 ft. per min., but for large wheels, on account of the difficulty of obtaining sound castings, the limit is in the neighborhood of 17,000 to 18,000 ft. per min. By carefully designing such wheels the radius of gyration may be made somewhat greater than that of a plain disk and the average of a number of cases worked out by the author gave the value of 0.78 *r*.

It will be understood that the permissible stresses in a cast steel wheel must be lower than those of a mild steel plate on account of the uncertainty as to the quality of the casting and the difference in the strength of the two, since with the latter, if the thickness is not too great, a perfectly homogeneous material can be obtained. For this reason the author has used fly wheels built up of ordinary commercial steel plate. As the strength of the material and the stresses may be accurately determined it is quite permissible to run such wheels up to 24,000 or 25,000 ft. per min., if desired, without the stresses exceeding more than about half the elastic limit. Although the radius of gyration of such a wheel is somewhat less than that of a well-designed cast steel wheel, the increase in velocity permissible more than compensates for this difference. In plants already installed, speeds of about 22,000 ft. per min. have been used because it was not desired nor necessary to go higher, but when the weight of the wheel is limited by considerations other than running economy, there is no reason why the higher limits given should not be used with perfect safety. Comparing a cast steel wheel having a peripheral velocity of 18,000 ft. per min. with a disk running at 22,000 ft. per min. this ratio of the weights, assuming the radii of gyration to be 0.78 and 0.707 respectively, will be

$$(18{,}000^2 \times 0.78) : (22{,}000 \times 0.707)$$

or

$$1 : 1.35$$

It will be seen that under ordinary circumstances a plain disk will weigh about 74 per cent of a corresponding cast steel profile wheel, and since the cost per pound is little, if any, higher, when the difference in weights is considered, the built-up wheel is actually cheaper.

In order to determine the weight of the fly wheel required to equalize any given load, it is necessary to determine the amount

of energy which it must give out each hoisting cycle. In the case of the Ilgner system, the load on the driving motor will be made up of the output of the hoist motor plus the losses in both the motor and generator, so that in order to maintain the line load constant the fly wheel must take care of all the excess of input to the generator above the mean value. The input diagram for the generator is easily obtained by taking the main points of the hoist motor diagram and adding the various losses corresponding to these points. For the sake of convenience the losses in the hoist motor and the generator may be assumed to consist of two parts; one, due to iron losses, friction and windage being constant; and the other, due to the copper and brush drop, varying with the square of the load. The excitation

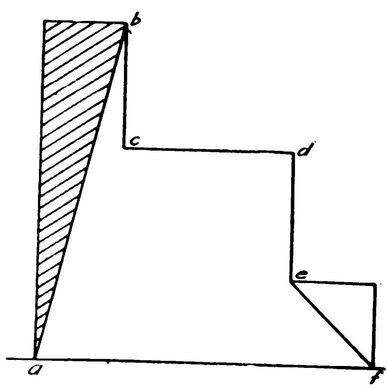


FIG. 8

is provided for separately and need not be considered when determining the generator input.

It should be noted that the power diagram and not the torque diagram must be taken as a basis, as the actual input to the hoist is the product of the torque and speed, being zero at the beginning of the trip and a maximum when full speed is obtained. When a motor is rheostatically controlled the difference between the power and torque diagrams is absorbed by the resistances, but with voltage control these losses are obviated. In Fig. 8 which is a load diagram for a Koepe hoist, the shaded portion represents the loss due to rheostatic control, and the area enclosed by *a b c d e* and *f* the power diagram.

The most convenient method for calculating the losses is to

plot a curve made up as above, which can easily be done when the characteristics of the machines which it is intended to use are known. The load diagram will be a sufficient guide as to the size of the hoist motor and the generator, the latter being taken as about 10 per cent larger than the former. When, as is frequently the case, the hoist returns energy to the system during retardation, it should be noted that the losses in the two machines must be subtracted from the values obtained from the load diagram. The input diagram for the generator having been determined, the mean output of the three-phase motor is readily obtained. From the various loads and the times that they are applied, the total input per trip in horse power seconds is found, and if this value is divided by the total time required for one

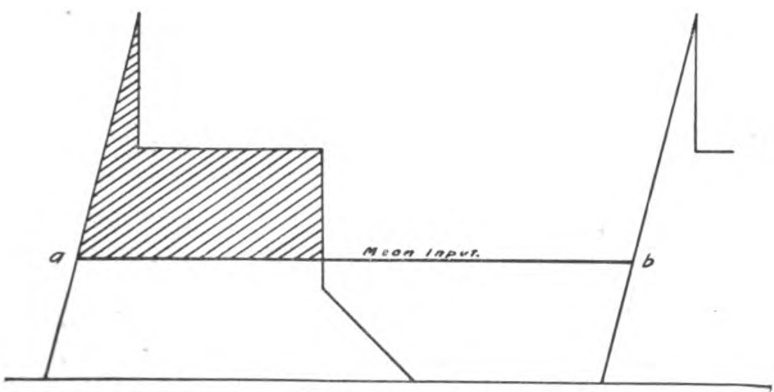


Fig. 9

trip, including the period of rest when loading and unloading the cages, the average input is found. Taking this as the motor output for the time being, the loads in excess of this value will have to be taken by the fly wheel. If energy is returned to the system by the hoist this value must be subtracted from the total before determining the mean input. Referring to Fig. 9 the line *ab* represents the mean input to the generator and the shaded portion the fly wheel output. It will be obvious that as the mean load is carried by the motor, the same amount of energy will be imparted to the fly wheel during the periods when the demand is below the average as is given up during the time when it exceeds this figure. Therefore at the end of the cycle the fly wheel will be running at the full speed again. Taking the

fly wheel output in h.p. sec., as found from the input diagram the weight required will be

$$W \frac{E' \times 550 \times 2g}{V^2 - V_1^2}.$$

when W = fly wheel weight in lb.
E' = fly wheel output in h.p. sec.
g = 32.2.
V = maximum velocity at radius of gyration in ft. per sec.
V_1 = minimum velocity at radius of gyration in ft. per sec.

The fly wheel output is multiplied by 550 to reduce it to ft. lb. sec. The actual output of the three-phase motor will be the mean load as found from the diagram plus the losses due to windage and friction of the fly wheel, the average slip regulator loss which is equal to half the maximum slip, and the power required to drive the exciter. The friction of the fly wheel bearings is readily found when the size of the bearings is known, an average value for the coefficient of friction being about 0.004. The windage loss is not easy to determine but from a number of experiments made by Dr. E. Becker in Germany on wheels varying from 6 ft. 6 in. to 14 ft. 6 in. in diameter and 4 in. to 31 in. wide, the weights being from 3 to 50 tons and the peripheral speeds 18,000 to 21,000 ft. per min., the following result was obtained,

$$\text{h.p.loss} = 0.0513\, V^{2.5} \times 0.093\, D^2\, (1 + 0.465\, B^2)\, 10^{-5}$$

for smooth surface wheels.

when V = peripheral velocity in ft. per sec.
D = diameter in ft.
B = width in ft.

The wheels tested gave results corresponding so closely to the above that it would appear to be fairly reliable.

In the case of the converter system only the part of the load diagram above the mean value is to be considered, the remainder having no influence on the balancing plant. Taking the loads in excess of the mean value found from the load diagram plus the hoist motor losses the actual output of the fly wheel will

be this amount plus the losses in the converter and equalizing machine, which must also include the excitation. The fly wheel weight is then determined in the same way as with the motor generator system. It should be noted that the average input to the motor must include the rheostatic losses at starting or, in other words, the torque diagram must be taken and not the actual power diagram, as with the Ilgner system. The real demand on the line will equal the average found as above, plus the losses in the equalizing system which are caused by the double conversion, and the fly wheel windage and friction. In the case of a motor generator system with a direct current driving motor, there is no loss due to the slip regulator, because all the regulation is in the motor field and the loss is negligible. With the converter system applied to a direct current plant there are no converter losses. These two systems contain the principles of all other equalizing arrangements and the same methods here indicated can be used for determining the characteristics of the different parts of any proposed system.

Economy of electric hoisting. When considering hoisting installations it is difficult to make any generalizations as to the economy, for each case must be considered separately. When mines have a power station already installed it is undoubtedly cheaper to adopt an electric hoist, even if it means an extension of the generating capacity, on account of the lower operating expenses and attendance, but whether it is better to have an equalizing system or not will depend on conditions. If the hoist is comparatively small possibly it will affect the total load very little. In the case of deep metal mines the hoisting load will usually be found to be quite a large proportion of the total, increasing with the depth. In order to obtain the benefits of an electric hoist in such a case, it is necessary to use some equalizing system to increase the load factor, and when this is done the hoisting cost per ton of material handled can be brought to a very low figure. When the costs of hoisting with a simple non-condensing steam plant and with an electric hoist are compared, the latter is undoubtedly the more economical, but when it is a question of using a modern compound condensing steam hoist with automatic cut off, a little more consideration is necessary. Under certain circumstances such a steam plant may have lower costs, but there are very few instances which, when properly investigated, do not show that the electric plant, if properly designed, is the more advantageous. In making comparisons care should be

taken to avoid using any theoretical cycle as a basis, for the only true ground to work on is the actual duty over a considerable period, taking into consideration the time when the hoist is idle, as well as when it is running. With an ordinary plant the actual useful work done may be from 50 per cent to 75 per cent

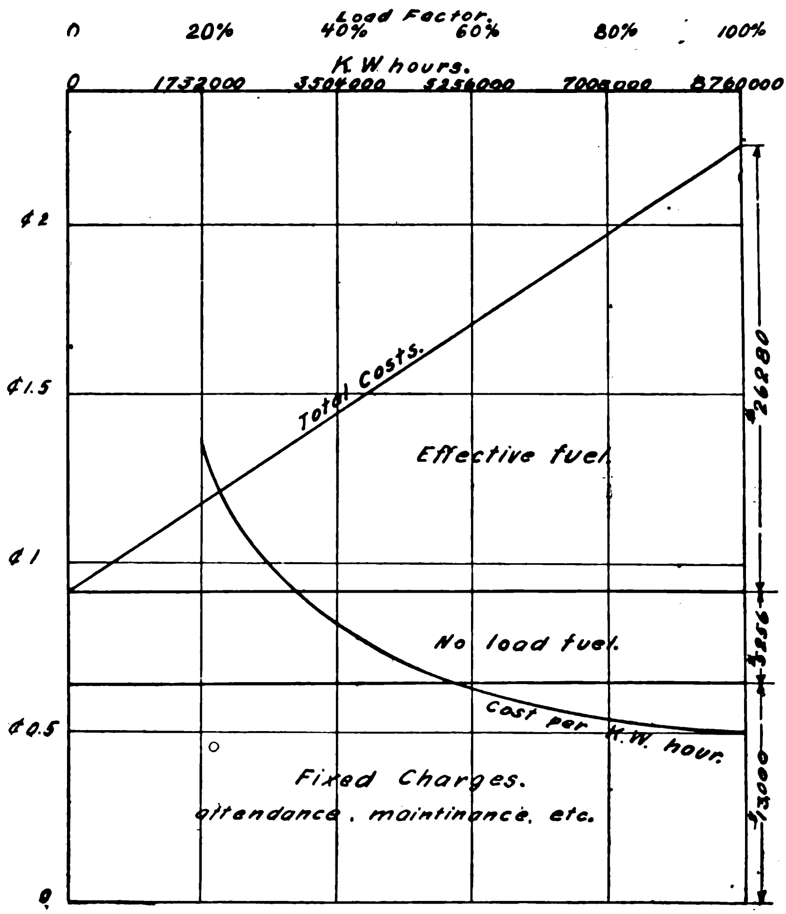


FIG. 10

of the possible output, depending on the circumstances. This may be to the advantage of the electric plant or otherwise. The load factor of an electric plant is the ratio of the mean input to the maximum, and the effect on a generating plant will depend on the other power requirements and the load factor. If, for

instance, the general load is 500 kw. and the load factor is 50 per cent, the generating capacity required is 1000 kw. The addition of a hoisting load of, say, 300 kw. with a load factor of 33 per cent will increase the required capacity to 1900 kw. and will reduce the load factor to 42 per cent. If, by means of an equalizing system, the hoisting load factor is brought up to 80 per cent, the total load factor will be 65 per cent. The cost of power with different load factors may be readily obtained if records are kept of the various items entering into the total. With a steam operated generating plant the total cost will be made up of fuel, water, oil and waste, interest, depreciation, attendance, maintenance and repairs. Practically the first two are the only ones which vary with the load and a certain proportion of them is also constant. As an approximate guide, it may be considered that the fuel consumption when running idle will be about 20 per cent of the full load value and the water about the same. The remaining four-fifths will vary directly with the load so that we have a condition represented by Fig. 10. Suppose, for example, a plant of 1000 kw. capacity, the capital cost of which installed is $80 per kw., the coal consumption at full load being 2½ lb. per kw. hr., the cost being $3 per hr. With interest at 5 per cent and depreciation also 5 per cent and maintenance, stores and attendance at $5000 per year, the total fixed charges will be $13,000. Assuming that water is free, the coal required, running light or a basis of 24 hours per day, is about 1752 tons, which at $3 amounts to $5256 per year, making the total constant charges $18,250. The capacity of the plant when running at full load continuously will be 8,760,000 kw. hr. per year and the effective fuel required to produce this output is $8,760,000 \times 2 = 17,520,000$ lb. or 8760 tons, costing $26,280. This together with the fixed charges makes a total of $44,536, giving a cost per kw. hr. of 51c. With 50 per cent load factor the effective fuel consumption would be 4380 tons, costing $13,140, and the total running cost $31,396. The output would be 4,380,000 kw. hr. per year so that the cost per kw. hr. is 72c. In this way a curve may be readily plotted and it will show how a balancing system reduces the cost of power by increasing the load factor. The above method is not absolutely correct, since other factors enter into the running costs, but it is sufficiently close to enable a fairly accurate estimate to be made, for any particular case. In order to find the average load factor for the hoist the total consumption per trip must be taken as a basis. In the case of a balancing system

the input may be considered as being made up of two parts, one being constant, representing the light running losses, and the other the total per trip minus this value. Supposing, for instance, that a plant is designed to equalize completely the load on the basis of 30 trips per hour, the input being 10 kw. hr. per trip and the light running losses of the motor generator set will be about 20 per cent of this figure, or 60 kw. hr. per hour. As designed, the load factor is 100 per cent, but if the average number of trips is 20 per hour the total consumption, instead of being 300 kw. hr. is $60+20\times 8 = 220$ kw. hr., and the load factor $\frac{220}{300} = 0.73$. From the daily or weekly output the real load factor of the plant may be obtained in this way and the actual running costs may be ascertained. When dealing with a steam plant the same methods must be adopted and it will be found that the losses when the plant is idle are often very great, and, although on a certain definite cycle the running cost may be worked out to a figure which approaches that of the electric plant, the average economy might be very much lower. The actual power consumption of a well-designed electric plant with a motor generator equalizing set has been found from a great number of tests to be about 1.6 to 1.7 kw. per shaft horse power, and for a plain hoist without any equalizing system, about 1.25 kw. is a fair figure. When considering the running costs the transmission losses must be taken into account. With an electric plant the line losses will be as a rule small, but with a steam hoist the condensation in pipes, etc., is generally appreciable.

In conclusion, it may be well to draw attention to a few advantages of electric hoists from an operating standpoint. The most important is the complete control afforded over the hoist when running, enabling the operator to work much quicker and with greater certainty. The ease with which the braking can be taken care of electrically makes it possible to manipulate the hoist with the greatest precision, the mechanical brakes being used only for holding the load. Under certain circumstances energy may be returned to the system by the hoist, which reduces the power consumption, but the main point is that it obviates the excessive wear on the brakes which would otherwise have to absorb this energy. Electric hoists may be fitted with devices for automatically reducing the speed and preventing overwinding, which are absolutely certain in their action, and on this

circuit voltage does not exceed $3\frac{1}{2}$ to 4 volts. The employment of preventive leads, however, allows the use of higher inductions per pole, and in general results in a somewhat smaller motor for the same rating.

Considering the second point, that of cost and adaptability for assembling, I have found on calculating suitable coils for the proposed 500-h. p. motor mentioned in the paper, that the sizes are rather startling, and one is inclined to the belief that the authors were so glad to find a place large enough to accommodate the choke-coils that the mechanical difficulties involved in the use of the external commutator looked small.

Space economy. The space available for the motor of a locomotive depends so much on the type of motor-mounting and drive, that comparisons on the basis of output of the motor designs of different types are misleading. It is of course allowable and proper, to compare locomotive performances provided they have been designed for the same class of service.

For motors mounted concentric with the locomotive axle similar to the New Haven motors, the desired freedom and standard wheel-flange-spacing fix the maximum length of motor, while the motor diameter allowable, depends upon the wheel size and the permissible clearance below the motor.

If a particular locomotive speed condition is assumed, the end clearances will be practically the same, and the size of motor that can be put in the space will increase with the increase in the driver size. For a particular case of this type of mounting, in which the same locomotive speeds are assumed for various sizes of drivers, the increase in horse power output, which can be put in the available space, will be approximately along a straight line, which indicates a 250-h. p. motor on 62-in. drivers and a 500-h. p. motor on 94-in. drivers.

The increase in motor weights will be somewhat more rapid than their increase in diameters, owing to the fact that the active electrical and magnetic parts will increase almost directly with the diameters, while the weight of most of the mechanical parts will increase more nearly as the square of the motor diameter.

Motors mounted horizontally, with one side supported rigidly on the axle, similar to the ordinary method of mounting motors on car trucks, gradually lose end-room as their sizes increase, on account of mechanical requirements of increasing space for larger gears, and their outputs do not work out on so simple a curve as the motors mounted concentric with the axles. This loss in end-room results in a double loss as it makes it necessary, for a given rating, to use a larger motor diameter. This increase in motor diameter requires a reduction in motor revolutions, on account of mechanical limitations, which in itself makes a larger diameter necessary. This increase in armature diameter, forces the gear centers further apart and increases the size of gears. A final balance is reached, above which, it is not feasible to mount motors in this manner on account of the gear sizes

and dead motor weight on the axle. This dead weight can be relieved by the use of quills which afford a spring support for the motor, and this makes it possible to increase the size of motor. The use of a quill, however, increases the gear centers, and this causes the limit due to the size of gear, to be reached sooner. Here it should be noted that the required range of locomotive speed plays an important part. The motor, for mechanical and insulation reasons, is designed for a certain limiting speed above which it must not be operated. If the continuous rating speed is chosen near or at the maximum speed, the smallest motor possible for the locomotive rating is obtained. As the continuous rating speed is decreased, the motor size increases. It follows, therefore, that from the standpoint of the motor design alone, the less the requirements of range in locomotive speed between continuous and maximum, the cheaper the motor will be. It is largely on this account, coupled with the mechanical requirements of locomotive riding qualities at high speeds, that locomotive costs are increased so much, for conditions where it is expected to operate in both freight and passenger service at quite different speeds. In general for this type of mounting, there is little or no gain in motor size by reducing the continuous rating locomotive speed below about 12 miles per hour.

Motors mounted directly above the axles and geared thereto through quills, are but one division of this general class of direct-gear drive and are subject to the same limiting conditions. The quill is, however, necessary in all cases with this type of mounting in order to relieve the axles, wheels and track, of the otherwise excessive dead weight.

When use is made of the combination drive employing gears and side rods, there is a distinct gain in the end-room space available for the motor, as in this type of drive, the entire space between the locomotive side-frames, which are generally plate-frames inside the wheel-flanges, can be utilized for the motor. The gears can be placed outside the wheels and there is not very much difficulty in making them any desired size. The driver sizes, wheel-base limits, and crank-throw are, in most cases, the determining factors. This increase in end-room makes a smaller diameter and higher speed motor possible, and hence a cheaper motor. This type of mounting gives almost as much end-room as that employing the straight side-rod drive. The latter has a slight advantage as it is possible with it to extend the motor up to the wheel-flanges and in fact to cut away part of the motor housing for a still further slight gain.

With both of these types of drive the diameter of the motor is limited by cab clearances. These last mentioned types of mounting, allow space that makes possible the largest sizes of motors desirable.

The combination drive is much more flexible and gives a better selection of motor speeds and driver sizes, as the gears

can be selected to get the desired locomotive speed. It is impossible with these last mentioned types of drive, to state the sizes of motor in terms of the ordinary methods of rating, without a definite limiting speed range, and so I will not attempt to state more than the preceding indications of the general limits.

E. H. Anderson: The paper brings out very clearly the difficulties of designing a single-phase commutator motor. The scheme of placing reactances in such connection as to theoretically reduce sparking is ingenious, to say the least. The criticism of the scheme is, that it does not make for simplicity. The simplest form of apparatus is more often the most enduring.

It appears from the text that the leads of the stationary winding are connected into the stationary commutator, although space and detail of construction are not shown. In order to take the motor apart for repairs, it is necessary to pull off a driving-wheel, or separate the stationary member, and in this case it becomes necessary to disconnect the winding and all the commutator leads coming from the lower half. The driving mechanism for the revolving brush-holders must be positive and rigid. No slack or looseness can be allowed, for the exact position of the brushes on a single-phase commutator motor is very essential for proper operation and speed. Such a motor as described, usually has about an 8-in. commutator and 18 in. of core iron between heads.

The power of a motor is dependent largely upon the length of core, and if all of the commutator length could be put into core, that is, by adding 8 in. to 18 in., it becomes possible to increase the power about 45 per cent. However, all the commutator length cannot be added to the core, for the reason that there must be a circular conduit at each end to allow the leads of the lower portion of the stationary member to be brought up to the stationary commutator. This will require approximately 3 in. on each end thus leaving 2 in. to be added to the core-length, giving 20 in. instead of 18 in., or an increase of 11 per cent. After the leads leave the conduit they must be spread around the commutator and held firmly, as well as properly ventilated. Usually from a given space, a certain amount of heat can be blown out, so that with a given efficiency only a given amount of work can be done in that space. The driving device for the revolving brush-holder rigging must take up some space on the axle. This will no doubt use up the spare 2 in. with the result that the iron core between heads is not increased.

The question naturally arises, is the taking away the commutator from the rotary member, and placing the same on the stator worth the complication? It appears from the paper that this scheme is best suited for single-phase axle motors for locomotives, and is limited to the construction shown, of mounting the stationary member on a quill and using quill-drive. It appears that there is difficulty in building within the limited space between wheels, a motor large enough to slip the wheels

and do the work usually required on the usual axle weight of 50,000 lb. The above refers to a single-phase commutator motor and this scheme with its complication is an effort to increase the size of motor.

The serious question about the construction, to my mind, is that it is not the simplest. A prominent railway company built and installed a motor on a single-truck car, which should act as a counterweight to the real motor. The motor was a chunk of cast-iron, with armature bearings on it, mounted outward on a single-truck car, and over-balanced the effect of the real motor, which was outwardly-hung on a single-truck car. This was put on as it was thought the real motor might tip up end wise and block the system. These motors were used for a long time, and gave no trouble, probably on account of their simplicity.

E. F. W. Alexanderson: The title of the paper opens a broad subject. There may be as many ways to look at it, as there are designers who have worked on the development of single-phase railway motors. I prefer to look at the subject in a somewhat different light rather than discuss the schemes presented in the paper.

In the design of any electrical apparatus, there is usually one requirement that is more severe than any of the rest, or one weakness in the type of apparatus considered to which most of the attention must be given, so that all the other features must be subordinate to that particular consideration. Most electrical machines are sold on the basis of a standardized commercial rating, and this rating is in most cases based upon the temperature rise during a certain test. Other features, like regulation, power-factor, efficiency, and overload capacity, are given as supplementary descriptions of the apparatus. The commercial rating of railway motors is based upon heating, usually upon the one-hour test at 75 degrees rise, and the adaptability of a railway motor to any specific requirement is usually judged by the heating of the motor. This generally accepted method for determining the service capacity of railway motors has been developed with reference to the motor of the wholly enclosed type.

The three principal limitations in the design of an alternating-current railway motor are heating, commutation, and starting torque; of these three, the starting torque is, however, the most important.

The first attempts to design the alternating-current railway motors were naturally along the same lines as those of the direct-current motors. The motors were completely enclosed, and the service capacity was determined from the heating characteristics. It was soon found, however, that owing to the lower efficiency of the single-phase motor, the temperature has a tendency to become considerably higher than in the direct-current motor. An increase in the size of the motor, in order to reduce the temperature, led to an increase in the weight of the trucks, car-body, and the control, so that the motors had to do more work than was con-

templated in the first place, and the desired reduction in heating was not obtained. At present it is accepted as a necessity by all manufacturers of alternating-current railway apparatus, that the motors must be cooled, either by natural or forced ventilation. As soon as forced ventilation is adopted in an alternating-current motor, the whole basis of the design is changed. The cooling that can be accomplished in this way is so effective, that heating is no longer the limiting feature of the design. Commutation difficulties can be entirely overcome at any normal operating speed, by application of a commutating field of suitable phase and strength. They can also be counteracted, to a great extent by the use of so-called resistance or preventive leads. The ruling feature is therefore the starting torque. This applies to the three-phase railway motor, as well as to the single-phase railway motor, although for entirely different reasons.

In the discussion of Dr. Hutchinson's paper on the Great Northern electrification, I explained that the reason why the three-phase motors exceeded their guaranteed capacity on the basis of temperature rise, with forced ventilation was not an accident. The starting torque was the most severe requirement, and as a matter of fact, the motors are able to slip the wheels of the locomotive, only with a necessarily small margin.

In the single-phase railway motor, the starting torque is limited by local heating on the brushes, commutator bars, and certain parts of the winding. Various methods have been devised to increase the starting torque of the single-phase commutator motors as much as possible. Although there may be a disagreement as to what methods are the most practical it seems to be a general agreement that some special methods must be used.

The starting torque of the single-phase commutator motor is limited by the voltage per bar on the commutator, and the current per bar in the winding. Generally speaking, it can therefore be said that the starting torque is proportional to the size of the commutator. The special methods that are used to increase the starting torque consist in providing means for either raising the voltage per bar or by means for raising the current per bar. In other words, both systems require space in the motor which could otherwise be usefully employed if the motor was intended for direct current.

The scheme presented by the authors of the paper is the first of the two mentioned principles for increasing the starting torque, carried to the extreme. The system is, according to the authors, very effective, but there is also every indication that it takes room in proportion to its effectiveness, and there is no convincing evidence in the paper that the space occupied by the motor with its elaborate non-sparking devices, will not be quite as large as the space of a motor of more familiar design.

This refers to the motor of the Seyfert type with rotating commutator shown on the photograph. The scheme of the detached commutator, apart from its complication, does not solve

the problem of space factor as it is worked out in the design shown in the paper, because no provisions have been made for materially increasing the diameter of the commutator, which after all is a measurement of the starting torque. A natural solution is however given by the use of side rods which allows the commutator as well as the rest of the motor to assume its necessary dimensions as well as its natural proportions.

It is interesting to observe that the results obtained by the four or five manufacturers of single-phase railway motors in America and in Europe, agree closely in regard to weight and space per horse power. In order to give some more concrete figures, as to the space and weight factor of moderate size single-phase motors, the following data may be mentioned. A 25-cycle motor of the series repulsion type designed for 36-in. wheels, has a weight of 5900 lb., and delivers 150 h. p. at 600 rev. per min. in accordance with standard rating. This is, as far as I can see, in close agreement with recent developments of motors of several other types and makes.

The various schemes employed for overcoming commutation difficulties cannot, therefore, be judged by the space factor or the weight per horse power. The nearest to a practical comparison is undoubtedly a test that has been embodied in the specifications for locomotives in connection with the contemplated electrification of two of the large western railroads, that the motor should be able to develop full torque at stand still for a specified time, one minute or five minutes. If the motors are compared on a basis like this, the type will undoubtedly be most favored, which offers the greatest simplicity of structure, and the easiest work for the repair man.

Mr. S. S. Seyfert: The discussion that has taken place, following this paper, has amply repaid us for going to the trouble of presenting a few ideas in the line of motor design. Perhaps the best reason for bringing up a subject like this is to find out what the chief workers are doing.

I would like to mention a few points, however, because it seemed to me during the discussion, that the non-sparking devices that are proposed were assumed to be a necessary part of the inversion of the relative positions of field and armature. It is not necessary to use these choke-coils in the case of a motor with external armature, and as a matter of fact I have often thought that it might be desirable to use resistance leads, only under certain circumstances, especially if the short-circuit volts are reasonably small. We have found it is extremely difficult to design a motor of so large size, with a reasonable short-circuit voltage per turn, for with a reasonable number of poles, say 12, the flux per pole on a 500-h.p. motor becomes so large as to produce 12 volts or more per turn on the armature circuit, and if we wish to reduce this voltage we would either have to tap into the half-turns or increase the number of poles.

In order to build a large single-phase motor, it is absolutely necessary to use a large number of poles, or use a high short-

circuit voltage per turn. I think however, that motors could be built on the resistance-lead principle, that would commutate well enough, and in that case the stationary character of the armature, with the available space for placing the leads, would enable us to design the leads somewhat more generously, and therefore their liability to burn out at starting would be less, which would mean a lessening in the cost of repairs and an increase in the reliability of service. I think it is plain, that with the ordinary construction of armature, in which the resistance leads are doubled upon themselves in the bottoms of the armature slots, they consume a large amount of valuable space, real motor space, and they add their heating to the total heating of the armature. In case of burn-outs, which are liable to occur at starting, the armature windings have to be undone to repair the leads. In this case, I can easily imagine an arrangement of the leads so that they might be replaced at short notice separately and in fact a lead might be replaced while the motor was running, if the winding of the armature was of the proper type. On the basis of resistance leads alone, dropping entirely the question of choke-coils, it would seem an advantage to have the leads so located, that they can be easily and separately repaired. This would compensate for a great deal of the otherwise complicated arrangement.

I would say another word about the length of commutator. One of the members who discussed the paper mentioned that the length of the commutator on the present New Haven motor was about seven or eight inches, and in case of the removal of this commutator we would gain that space. I find, if we attempt to build a 500-h. p. motor, that the commutator would be about a foot long. In this case, assuming the commutator on the motor concentric with the axle, we would gain a foot of space by removing the commutator. Should we decide to make the commutator concentric with the armature—this one foot of space needed would force us to a greater driving-wheel diameter. It should be plain, therefore, that the increase in gross length of useful iron made possible by the removal of the commutator would be 12 inches instead of the seven or eight inches, as would be the case in changing a 250-h. p. motor. We were driven to that construction to get the necessary rating on a direct-connected motor for 62-in. drivers.

As to design, the inverted motor has among others, the following advantages:

1. The long external yoke or armature core has to carry the effective armature flux only, whereas, in the old type of motor, the corresponding core has to carry the total field flux.

2. The placing of the armature externally allows the use of a wider and shallower armature slot, resulting in a better commutation constant and a slightly better power-factor. The compensating slots through the poles must be deeper in this case, which condition may be easily met. Because of the comparatively low voltages at which single-phase motors must operate, it has

been found somewhat difficult to satisfy the direct-current commutating condition on a motor of large size with such a small number of poles.

3. The air-gap periphery is somewhat increased in the case of the external armature motor mainly because the armature requires less radical depth than the field.

4. The end-windings of the compensating-coils are very much shorter, as was mentioned in the paper.

We made some experiments on core losses in field and armature,

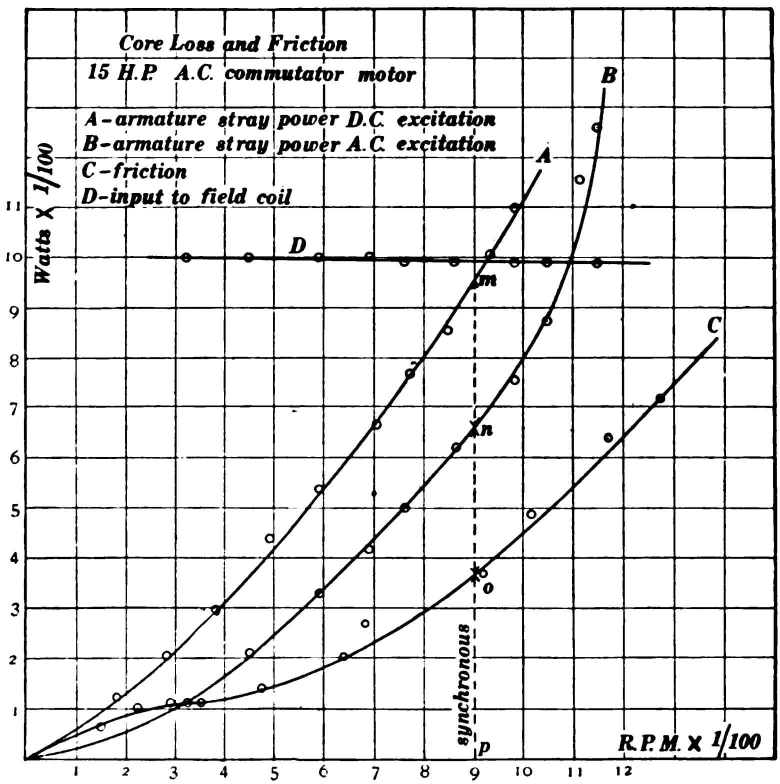


FIG. 13

which might be interesting at this juncture. For some time Dr. Franklin and myself were under the impression that the core losses per unit of volume in the armature of the alternating-current motor should diminish as synchronous speed is reached. Upon going into the theory of the matter this seems to be so, but for some reason, the core losses actually increase somewhat with speed. The experiment was performed on a single-phase motor of the ordinary type, and the results are shown in Fig. 13.

In the first place, a constant direct current of 30 amperes was

supplied to the field. The armature was rotated at a series of speeds up to and beyond synchronous speed.

Curve *A* gives the total input to the rotating armature from the driving motor; curve *C* gives friction loss in the motor tested so that *m o* represents the core loss in the armature.

In the second place a constant alternating current of 30 amperes effective value was supplied to the field. Curve *B* gives the corresponding core loss as measured by the driving motor. Curve *D* shows the watts input to the field-coil throughout the test. These curves show that the armature core losses in the aternating-current motor are not as great as they would be for the same effective values of induction on direct current. It is shown, however, that the core loss, in both cases, increases with speed, growing very rapidly above synchronous speed. This may be due to the fact that the losses caused by the bunching of flux by the teeth are such a large percentage of the armature core loss.

In the paper it is stated that we selected the 10-pole type of motor; we found later that 12 poles would have been better for it is well known that the larger the number of poles on the motor, the less its weight per horse power, because the individual magnetic circuits are less bulky, and the cross-sections of the core, both field and armature, are less. By going to 12 poles we could make a better machine, one that would commutate better and have a smaller short-circuit voltage.

President Stillwell: I am sure the Institute owes its thanks to Dr. Franklin and Professor Seyfert for the very interesting and suggestive paper which they have presented. It is always an advantage to look at a subject from another point of view, and I am sure that the engineers who are accustomed to the designing of motors of these types for commercial service will be glad to agree with me, and in a judicial spirit examine their own work very carefully to see if there be anything in this suggestion which might be utilized. I do not propose to enter into the discussion, but one or two points have occurred to me which might be mentioned to advantage, and one is that the argument in favor of the increase in output in proportion to dimensions are greatest in the case of multiple unit equipment, and in which case I think the paper makes no suggestion as to the location of the commutator and its leads.

In the case of the electric locomotive, taking the state of the art as it existed when the New Haven locomotives were designed, the designers were undoubtedly cramped for room in attempting to place the motors underneath the floor of the locomotive, but the tendency is now, I understand, rather towards raising the motors and gearing to a shaft, in which case the argument in favor of separate commutator and its leads from the field armature is somewhat minimized. I will now call upon Dr. Franklin to close the discussion.

Prof. W. S. Franklin: In regard to the location of the detached commutator in the multiple-unit car I may say that Professor

Seyfert and I have considered that matter in some detail after a consultation with Messrs. Gibbs and Hill, and we came to the conclusion that a very great advantage would be realized by placing the motor on one side of the axle, and the commutator on the other side of the same axle, taking the commutator leads across through a covered passageway over or under the axle.

In regard to the general question of detaching a commutator, I wish you to consider what a commutator really is. A commutator is a switchboard, and it is proper to detach a switchboard from the machine which it controls. I never saw a power house with a switchboard placed inside of the dynamo! I only make use of this evidently exaggerated statement in order to emphasize the fact that we have perhaps become too much accustomed to a certain point of view. Perhaps, after all, the detached commutator is the rational and practical thing, and yet I have enough respect for practical engineering to know that the question must ultimately be answered in practice. I do not know for certain whether the detached commutator is the best thing, and neither does anybody else know. It is a question which can be decided only by an actual and long-continued trial under practical conditions.

In regard to the importance of simplicity which has been emphasized by Mr. Anderson, I wish to point out that the motor which Professor Seyfert and I have designed is about the nearest approximation that I know of to a " piece of cast-iron."

In answer to Professor Kintner's question concerning the short-circuit voltage I would say that the short-circuit voltage of our No. 5 (500-h.p.) motor is 12 volts per turn, that is, 12 volts in a single turn around the field-pole.

The question was raised as to the necessary size or carrying capacity of the individual choke-coils. Concerning this point, it is stated in the paper that a short-circuiting arrangement can be provided so that choke-coils or resistance leads can be cut out or in at pleasure. The frequency of commutation is low at starting, and under these conditions one needs high resistance in the leads, whereas the inductive choking is rather small. At high speed, on the other hand, the choke-coils are extremely effective without any resistance. Therefore at starting, very high resistances might be inserted in the leads and these resistances might be cut out with increase of speed after starting.

I wish particularly to emphasize a point which is brought out in the paper, namely, that one of the most important features in the suggested design is, that you can treat the problem of starting and the problem of running as two distinct and separate problems; you can put large resistance in your leads at starting, and when the machine reaches a certain definite speed you can cut out as much resistance as you please by a ring which is made to drop between terminal bars in a manner which will at once occur to any designer.

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EDUCATION FOR LEADERSHIP IN ELECTRICAL ENGINEERING

BY SAMUEL SHELDON

Introduction. There seems to be a prevalent opinion that engineers in general, and electrical engineers in particular, do not occupy as important positions among the leaders in this country as engineering enterprises occupy in affairs in general. An attempt is made in this paper to determine how far this opinion is warranted, to give the characteristics of electrical engineering leaders, to consider the educational advantages which they have enjoyed, to formulate those essential characteristics of leaders which can be imparted to the individual by educational processes, and to discuss some of the problems met by educators in carrying on these processes.

The Importance of Electrical Engineering. This can be determined best from a statistical study. The following data concerning individuals and money values have their origin in various United States Census reports. Although they refer to different periods during the last decade, they are sufficiently related to warrant their use in this connection. The importance of an item is expressed by the percentage ratio which its occurrence bears to all occurrences in the same class.

The opportunities for achieving great distinction seem limited to professional service, the enumeration in the table including artists, architects, authors, scientists, clergymen, dentists, engineers, journalists, lawyers, federal, state and municipal officials, army and navy officers, physicians and teachers. However, of those having non-professional occupations there are 73,384 bankers and 792,887 merchants, a few of whom have achieved distinction in their occupations.

TABLE I. OCCUPATIONS OF PERSONS IN THE UNITED STATES. 1900

Occupations	Persons	Importance
All occupations	29,285,922	100.0
Professional service	1,264,737	4.3–100.0
Electricians	50,782	4.0
Civil engineers	20,153	1.6
Mechanical and electrical engineers	14,440	1.1
Mining engineers	2,908	0.2
Engineers and electricians	88,283	7.0
Engineers	37,501	3.0
Telegraph and telephone lineman	14,765	0.05
Telegraph and telephone operators	75,080	0.26
Machinists	283,432	0.97
Engineers and firemen (not locomotive)	224,546	0.76

TABLE II. DISTRIBUTION OF CAPITAL IN THE UNITED STATES

Distribution	Amount in dollars	Importance
Total wealth of the United States	$120,000,000,000	100.0
Electric railways (1907)	3,774,772,096	3.1
Central stations (1907)	996,613,622	0.8
Electric manufactures (1905)	174,066,026	0.1
Telephone and telegraph (1907)	1,034,909,579	0.9

The amounts set opposite to electric railways and to telephone and telegraph represent the total par value of outstanding stock and bonds and include permanent and other investments. In the case of central stations the amount represents the total cost of plants.

Assuming that one-half the group of mechanical and electrical engineers belongs to the latter class, the number of electricians and electrical engineers in the United States constitutes 4.6 per cent of those giving professional service, and 4.9 per cent of the total wealth of the country is invested in electrical industries.

The Importance of Electrical Engineers. In order to estimate the importance of engineers in the control and direction of the affairs of the country use has been made of the book "Who's Who in America," which has been employed frequently in connection with statistical studies of educational and sociological problems. It contains the biographies of several thousand persons whose achievements are widely known in some worthy

line of effort. It arbitrarily includes the names of Cabinet members, Congressmen, Governors, United States and State Appellate Judges, general officers of the Army and Navy, Bishops, College and University heads, and heads of the leading national societies devoted to educational and scientific aims. In the preface of the 1906–7 edition there is a statement as to the comprehensiveness of the book, namely, that it

"has reached a stage of such completeness in selection that very few contemporary Americans of the very highest rank of prominence will be missed from its array of notables."

All the names of Members of the American Institute of Electrical Engineers and 815 of the 4312 names of Associates, as appearing in the catalogue of members under date of August 1, 1907, have been compared with the list of names appearing in the 1906–7 edition of the above book. A similar comparison has been made with 1017 of the 2084 Members of the American Society of Civil Engineers, employing a list of members issued under date of February 1907. The number of engineers as well as the number of non-civil engineers whose names are to be found in the geographical index of the 1908–9 edition of "Who's Who in America" has also been determined. The resulting estimates of these investigations are embodied in Table III.

TABLE III. NAMES IN "WHO'S WHO"

Source of names	Number	Importance
"Who's Who" 1906–7	16,216	100.0
Members of A. I. E. E. (546)	98	0.8
Associates of A. I. E. E. (4312)	32	
Members of A. S. C. E. (2084)	259	1.6
"Who's Who," Geog. Index 1908–9	18,418	100.0
Civil Engineers in index	191	1.0
Non civil engineers in Index	367	2.0
Engineers in Index	558	3.0

Of all the names appearing in the Index, 3 per cent are of engineers—the identical percentage represented by engineers as compared with all those giving professional service in the United States, as shown in Table I.

Again of all the names appearing in the 1906–7 edition of "Who's Who" 1.6 per cent appear also in the list of members of the American Society of Civil Engineers for 1907—the identical percentage represented by civil engineers among those of pro-

fessional occupation. It is probable that this list includes nearly all those holding a place in "Who's Who" because of prominence in civil engineering. The number of names, 259, is larger than that of those appearing with the special qualification "civil" in the Index, namely, 191, but there are doubtless prominent civil engineers whose names appear in the Index as "engineers" without any qualification.

It is also probable that the number of names from the Institute membership, appearing in "Who's Who," 130, includes

TABLE IV. DEGREES HELD BY NOTABLE MEMBERS

Degrees	Number	
Without Degree		19
Bachelor's Degree		39
B. A.	16	
B.S.	16	
B.Ph.	4	
B.M.E.	1	
LL.B.	2	
Engineering Degree		45
M.E.	24	
E.E.	10	
C.E.	4	
Annapolis	6	
West Point	1	
Master's Degree		21
M.A.	13	
M.S.	6	
M.Ph.	1	
M.M.E.	1	
Doctor's Degree		35
Ph.D.	22	
Sc. D.	7	
LL.D.	4	
M.D.	2	

nearly all those inserted therein because of prominence in electrical engineering. The number of non-civil engineers, 367, whose names appear in the Index, among whom are included electrical, mechanical, and mining engineers, as well as a few civil engineers, serves as a check upon this estimate. If, therefore, the electrical engineering profession be considered as embracing those who are designated as "electricians" by the United States Census enumerators, the importance of its leaders among the country's leaders, 0.8 per cent, is materially less than the importance of the profession, 4.6 per cent, and of the

related capital invested, 4.9 per cent. If, on the contrary "electricians" be not included, and they cannot properly be included in the professional class, the importance of its leaders is slightly greater than the importance of the profession, but materially less than the importance of related capital. If "electricians" be considered as the educational product of trades schools, as distinguished from technical schools and colleges, the electrical engineer must still be considered, for the immediate purpose, to be not as important as his affairs.

The results thus far obtained lead to the conclusions that engineers are as notable as they are numerous and that electrical engineers are very much over-capitalized. It is possible that this may bear the interpretation that electrical engineers are overworked and that, therefore, the electrical engineering profession offers unusual opportunities for young men.

The Characteristics of Notable Electrical Engineers. The number of academic degrees and their designations, held by the 98 notable Members of the Institute, are given in Table IV.

The distribution of those degrees among the 98 Members is given in Table V.

TABLE V. DISTRIBUTION OF DEGREES

Number of Degrees	Holding Members
0	19
1	42
2	21
3	10
4	4
5	2

Of the Members without degrees 11 had the advantages of college instruction but did not graduate and 14 of the holders of one degree pursued post graduate studies without receiving a second degree. The percentage of Members holding college degrees is 80.6 and of those who have had college instruction is 90.0. The corresponding percentages for those whose names appear in "Who's Who" are 56 and 70, respectively. These Members, therefore, appear to have enjoyed unusually extended educational advantages. Especially noticeable, in the preceding tables, is the large number of bachelors', masters' and doctors' degrees, and the relatively small number of engineering degrees. This is significant as to educational influences but has un-

doubtedly resulted from necessity and not from intention, as will be concluded from a consideration of Table VI, which gives the age distribution of 94 notable electrical and 122 civil engineers. It should be remembered, however, that some institutions bestow a Bachelor's degree after completion of courses nearly identical with those offered by many other institutions as leading to engineering degrees.

TABLE VI. AGES OF NOTABLE ENGINEERS

Ages	Electrical	Civil
30– 34	3	0
35– 39	17	7
40– 44	22	20
45– 49	31	12
50– 54	5	13
55– 59	8	18
60– 64	5	16
65– 69	1	14
70– 74	2	11
75– 79	0	5
80– 84	0	2
85– 89	0	3
90– 94	0	0
95–100	0	1

The average age of the electrical engineers is 46.2 years, of the civil engineers, 57.5 years, and of all those whose ages are given in "Who's Who," 53.3 years. The electrical engineers are therefore too young as yet to be properly judged as to their achievements. Inasmuch as the greatest number of students are graduated from college at the age of 22.5 years, the average of the notable engineers who are the subjects of this study were graduated from college in 1883. As stated by Professor Norris, the beginnings of formal electrical engineering study in educational institutions in this country were made about 1880. This explains the smallness of the number holding the degree of electrical engineer; namely, 10 out of 140. If a subsequent and comparative study be made along the lines herein pursued in 1913, or better in 1918, the values of special educational methods may be better estimated.

Before undertaking to determine the educational attainments of the subjects of this study there must be a recognition of the fact of original nature and of its great importance in determining life's progress. Thorndike says:

"It is wasteful to attempt to create and folly to pretend to create capacities and interests which are assured or denied to an individual before he is born. The environment acts for the most part not as a creative force, but as a stimulating and selective force."

It must be postulated that persons with a record of extensive achievements are constituted of the proper clay and that notable electrical engineers have inherited the original traits essential to greatness.

Estimates of the acquired traits of these engineers have been obtained from five of their contemporaries who are considered to have good judgment, and who know many of them personally and all of them by reputation. Each of them has selected and graded ten names of those who appeal to his judgment as of greatest achievement in the electrical engineering profession. Each has also given a rough estimate as to the extent of attainment of five fundamental acquired traits an exceptional amount being marked 1 a noticeable deficiency being marked 3, and all other conditions being marked 2. The five traits were mental training, distributed and comprehensive knowledge, facility of expression, discipline of the will, and aesthetic taste. The results of these estimates concerning the twelve of highest rank are embodied in Table VII. The estimate-marks, corresponding to each trait and each person, are arranged in order one above the other, so that the mark of any judge is always in the same row relative to the top row. One judge, after selecting his ten most important individuals, seemed unable to grade them without first analyzing their traits, although he was unaware of the fact that he was to be requested subsequently to make such an analysis. This person is generally recognized as having superior judgment, and this incident is illuminating as indicating the mental processes leading up to his making of a decision. His estimates are to be found in the fifth row from the top in the table.

In the first column the individuals are represented by the letters of the alphabet. In the second column are shown the perspective or bulk estimates of the relative ranks of the individuals as given by the first four of the five judges. A numerical average of these estimates is also appended. The arrangement of individuals is not in accordance with these averages, for weight is given to the extent to which an individual appears in the lists of all the judges and to the extent of his acquirements. Thus A, B, C, and D appear in all five lists; E and G in four;

TABLE VII. ESTIMATES OF ACQUIRED TRAITS

Individual	Bulk estimate of rank		Training of the mind		Comprehensiveness of knowledge		Facility of expression		Discipline of the will		Aesthetic taste	
A	2 3 1 1	1.75	1 1 1 1 1	1.0	2 1 2 2 1	1.6	1 1 1 2 1	1.2	1 1 2 2 2	1.6	3 1 2 2 2	2.0
B	1 2 2 2	1.75	1 2 1 1 1	1.2	1 2 2 2 1	1.6	1 2 1 1 3	1.6	1 2 3 2 2	2.0	2 3 3 3 2	2.6
C	4 1 4 3	3.0	1 1 1 1 1	1.0	1 1 1 1 1	1.0	1 1 1 1 1	1.0	1 1 1 1 1	1.0	1 1 1 1 1	1.0
D	8 4 5 7	6.0	1 2 1 1 1	1.2	1 1 1 2 1	1.2	1 1 1 1 1	1.0	1 1 1 3 1	1.4	3 3 3 3 3	3.0
E	5 5 — 4	4.66	1 3 — 1 1	1.5	1 2 — 3 1	1.75	2 2 — 1 2	1.75	3 2 — 3 3	2.75	3 2 — 3 2	2.5
F	— — 3 5	4.0	— — 1 1 1	1.0	— — 1 1 1	1.0	— — 1 1 1	1.0	— — 1 1 1	1.0	— — 1 2 1	1.3
G	— 6 7 10	7.66	— 1 1 1 1	1.0	— 1 1 2 1	1.25	— 1 1 2 1	1.25	— 1 1 1 1	1.0	— 1 1 1 1	1.0
H	— 7 — 6	6.5	— 1 — 1 1	1.0	— 1 — 3 1	1.67	— 1 — 3 1	1.67	— 1 — 1 1	1.0	— 1 — 1 1	1.0
I	3 — — —	3.0	1 — — — —	1.0	1 — — — —	1.0	1 — — — —	1.0	1 — — — —	1.0	1 — — — —	1.0
J	6 10 — —	8.0	1 2 — — —	1.5	3 2 — — —	2.5	3 2 — — —	2.5	3 2 — — —	2.5	3 2 — — —	2.5
K	— 9 8 —	8.5	— 1 1 — —	1.0	— 1 1 — —	1.0	— 1 1 — —	1.0	— 1 1 — —	1.0	— 2 1 — —	1.5
L	9 — — 8	8.5	1 — — 1 —	1.0	2 — — 2 —	2.0	2 — — 3 —	2.5	3 — — 2 —	2.5	3 — — 2 —	2.5
Group average				1.12		1.46		1.46		1.56		1.83

F, H and K in three; J, K and L in two, and I in but one, as will appear upon inspection of the remaining columns.

Individuals C and F hold unique positions. Of these C has a perfect score as to acquired traits, but in bulk estimate he is ranked first by one judge, second by another, and fourth by two others. A nearly perfect score is held by F, but he appears on but three of the five original lists. These apparent inconsistencies are perhaps to be explained by the facts that C has had too good taste to pursue glory or wealth while F is young and may yet have his opportunity.

The average of the estimates of the acquired traits of this group of twelve picked men shows three things: first, these men have broadly developed their faculties and have acquired to a large extent the five fundamental traits; second, they are especially characterized by their well trained minds; and third, if it be considered desirable to modify existing educational methods so as to improve upon the character of the leaders, as exemplified by the individuals of Table VII, attention should be directed toward those educational processes which result in comprehensiveness of knowledge, facility of expression, discipline of the will, and a development of an aesthetic taste.

The Acquired Traits of Leaders. Trained minds are so predominant in the Institute that a treatment of the nature of mental training and the points of differentiation between trained and untrained minds is considered unnecessary.

The extent of knowledge is nearly infinite and few have any realization of how great it is. As an illustration, in the Dewey decimal system of cataloguing books—the system in use in most of the large libraries—to each book is assigned a number which classifies it both as to its contents and as to its location upon the shelves. The first integer of its number places it in one of the following ten classes:

0. General Works.
1. Philosophy.
2. Religion.
3. Sociology.
4. Philology.
5. Natural sciences.
6. Useful Arts.
7. Fine Arts.
8. Literature.
9. History.

Each of these classes represents a large field of human interest which can be estimated as to its extent by the number of printed books which exist as records of achievements in it. It cannot be stated truthfully that any one class is more extensive than another. Uniform distribution of books does not exist in individual libraries, but large libraries differ materially in their distributions. For instance, Brooklyn public libraries are especially strong in Sociology and Literature, but are not weak in any class.

Each of the ten classes is subdivided into ten sub-classes, which again in turn are each subdivided into ten sub-sub-classes and so on so far as may be necessary. The book receives in its number a succession of integers which successively locate it in the subdivisions of the system. In this system electrical engineering bears the number 621.3, being a subdivision under mechanical engineering, which latter is itself a subdivision under engineering, which last is a subdivision of the main class, Useful Arts. An electrical engineering book may also bear the number 537.8, as comprehending an application of electricity, which is a part of physics—one of the natural sciences. Therefore electrical engineering knowledge, as thus measured by the location of the books which record it, has an importance, with reference to the whole domain of knowledge, of two parts in 10,000 or two one-hundredths of one per cent. Of course this is not a true indication, and it would be sensational to claim that palingenesis, hermeneutics and manichaeism are fully as important as electrical engineering. But it serves to call attention to the fact that electrical engineering is a very highly specialized field for human endeavor and those who labor in it should not permit themselves to be confined to its limits.

That it is desirable for college students to gain at least a superficial knowledge of all fields of human achievement is being recognized by many educators. Harvard University has recently adopted the following rule which will go into effect with the class which is to enter next fall:

"II. For purposes of distribution all the courses open to undergraduates shall be divided among the following four general groups. Every student shall distribute at least six of his courses among the three general groups in which his chief work does not lie, and he shall take in each group not less than one course, and not less than three in any two groups. He shall not count for purposes of distribution more than two courses which are also listed in the group in which his main work lies. The groups and branches are:

1. Language, Literature, Fine Arts, Music.
   (a) Ancient Languages and Literatures.
   (b) Modern Languages and Literatures.
   (c) Fine Arts, Music.
2. Natural Sciences.
   (a) Physics, Chemistry, Astronomy, Engineering,
   (b) Biology, Physiology, Geology, Mining.
3. History, Political and Social Sciences.
   (a) History.
   (b) Politics, Economics, Sociology, Education, Anthropology.
4. Philosophy and Mathematics.
   (a) Philosophy.
   (b) Mathematics."

Leaders as a type have at least a superficial knowledge of the subject matter of all these groups and a full knowledge of that pertaining to at least one group. Formal education of engineers always comprehends some material of the second and fourth groups but is frequently deficient as to the first and third groups. Under such circumstances the graduate attains a knowledge of things and his thinking self, whereas he is left ignorant concerning the methods of thought and of action of man and men. Such ignorance is fatal to leadership, for the very word implies a man to lead and men to follow.

Facility of expression, spoken, written, or wrought, is essential as a vehicle for the conveyance intact of the definite concept of the brain of the man to the minds of other men. Other things being equal, the engineer who can speak effectively, as well as write, is the engineer who will exert the widest influence. Skill in the oral presentation of a plan, in the defence of a position, in the advocacy of a reform, or even in the making of a graceful and apposite response to a toast, has largely contributed to many a man's success. It is especially desirable for those who hope to occupy positions of executive responsibility.

To say that a disciplined will is essential to leadership is to utter a commonplace. In these times of intense life, when fatigue prevails, when haste kills perfection and thought robs sleep, it is indeed a luxury to remain a leader. Will's control of desire must be absolute.

That elusive trait, aesthetic taste, is essential for admission to the aristocracy of culture. It must ever remain indefinite and will not submit to standardization. While some of its elements may be present at birth others may undoubtedly be acquired, with a resultant modification of the complex.

Doctor Johnson distinguished between natural and achieved

taste. He said that if he had no duties and no reference to futurity, of all things he would like to drive briskly in a post-chaise with a pretty woman at his side. This was his natural taste. At the same time he said to Boswell:

> " Do not, Sir, accustom yourself to trust to *impressions*. By trusting to impressions a man may gradually come to yield to them, and at length be subject to them, so as not to be a free agent, or what is the same thing in effect, to suppose that he is not a free agent."

That is, our natural likings and dislikings are no safe guides; they must be controlled by education.

It seems evident that a man cannot become a leader of men if he be proscribed from intercourse with those who are wisest and most influential.

The Educating of Engineering Leaders. If it be assumed that engineering students, to become leaders, must acquire by education the fundamental traits which have been discussed, present methods pursued in their education could be improved upon.

Consider, first, existing institutions which have the usual requirements for admission and which bestow an engineering degree after four years of work. Their courses and methods could be so modified as to better the chances for leadership of all their students. The modifications should be three-fold and as follows: (1) a new system of selection of entering students should be adopted, (2) new subjects and methods should be introduced, and (3) time must be found for new subjects. The details of these modifications lie without the scope of this paper, and the wisdom of attempting them is questionable, for existing institutions, which are supported by the state, should be inclusive rather than exclusive, and those which depend upon distributed philanthropy must ever present the plea of extended usefulness.

A more discriminative system of selection at entrance would undoubtedly decrease the number of students and increase their average age. Of course a better resulting quality of product would be expected after four years. The great advantage to be obtained, however, by this discrimination, is the elimination of students of harmful influence, whose characters or circumstances militate against earnestness in endeavor and discipline of desire.

One subject of tremendous educational importance is recommended for consideration, namely, an extended study of literature as an art by the appreciative method. Art orders experience by the imagination, employs particularizations presenting truth concretely, and appeals to the emotions, to the will, and to the

taste as well as to the intellect. Literature is preeminent over the other arts—for its range of suggestion is the widest, it offers the most complete and definite intellectual content, and it represents life most fully. Its study develops the imagination and as Woodberry says:

> " So far as we realize the world at all beyond the limit of our private experience of it, we do so by the power of the imagination acting on the lines of reason. * * *. The scientist lights his way with it; the statesman forecasts reform by it, building in thought the state which he afterward realizes in fact; the entire future lives to us—and it is the most important part of life—only by its incantation."

It is significant that, of the 35 volumes which constitute the five-foot-shelf library of Dr. Eliot and which are considered by him to contain the elements of a liberal education, 22 have been classed by an expert cataloguer as " literature ".

The education of leaders and of all engineers does not cease until their retirement and the problem in hand relates to what may be termed their formal education. The general type of engineering leader has enjoyed more formal education than would be represented by the ordinary four-year course. A modification of this course so as to make it an equivalent would probably result in a corresponding rise in the average age of graduation. Those who recognize the long time required make different recommendations as to how it should be occupied, as an arts course followed by an engineering course, an engineering course followed by an advanced arts course, or a simultaneous pursuit of an arts and an engineering course. The last has some points in its favor, for maturity is an important factor in the successful pursuit of some arts as well as of some engineering subjects. But all these plans are faulty, in so far as they contemplate the inclusion of arts courses as they are at present taught in the ordinary college. There is a total lack of adjustment between the colleges and American life, as evidenced by a series of papers on this subject presented by prominent educators at the last Baltimore meeting of the American Association for the Advancement of Science. Especially evident is the lack of coördination between the arts courses and the engineering profession. Until the demands of law, of medicine and of trade are met by adequately modified curricula and methods of teaching a marked improvement cannot be expected in a plan of engineering education which includes this instruction.

But is it not folly to attempt to educate all when the presence

of the many who are sure to fail impedes at every step the progress of those who are destined to succeed? Institutional rivalry and individual ambition may say nay, that it is the way of democracy. But, if West Point, with its 500 cadets, can so adequately supply the leaders for 80,000 armed men, could not an engineering school of similar proportions supply the leaders of engineers? With the assurance of continued opportunities for promotion, would not choice residues follow each process of elimination? What might not a professor accomplish with such material? With practical skill, acquired in the post graduate laboratory of organized experience, what difficulty could be encountered in the construction of a Panama Canal? Is not the performance of such a task of greater value to civilization than that relic of barbarism—a victory at arms? The entire feasibility of such an institution makes one long to see it building. If Federal support be lacking, why not that of those whose wealth increases each day as the sweat pours from the face of the engineer?

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ELECTRIC MINE HOISTS

BY D. B. RUSHMORE AND K. A. PAULY

Of primary importance in mine installations is the hoist, which has a very direct bearing on the successful operation of a mine. Conditions vary greatly with different mines, and especially in different localities. Such factors as depth, incline, the number of levels, permissible or desirable speeds, conditions of ore, etc., are always more or less special in each case. Veins of ore are never exactly duplicated, and the nature of the ground through which shafts are sunk may considerably modify permissible values. As mining laws are made by the different states they necessarily vary somewhat, and, even when not fully observed, they introduce factors which qualify the conditions of hoisting men and ore. The amount of timbering required is often of importance as relating to hoisting conditions. Methods of loading ore affect the time required, as also does the question of the use of cars or skips. Safety precautions must be very carefully considered, and the number of men in each mine, the number of compartments, and often the method of removing water from the mine must have careful consideration.

While a general discussion of the subject of hoisting is possible, most cases are entirely special and can be considered only in connection with the peculiar conditions pertaining to that particular installation.

The cost of installation of the hoisting plant may be an appreciable amount, while the cost of raising the ore may be but a small part of the total operating charge. In many cases, however, the output of the mine is limited by the capacity of the hoist, and the latter thus becomes of the first importance. Where shafts have not been sunk to their final depths the conditions

of operation are of necessity constantly changing, and it is impossible to predetermine with exactness the precise conditions of operation which will be followed in practice.

Power for Mines. Power is used for drilling, tramming, pumping, ventilating, hoisting, compressing air, crushing rock and for many minor operations. In coal mines, the washeries and breakers, and in metal mines, the mills and concentrators, are ordinarily located in proximity to the shafts. The problem of lighting always exists.

Owing to the distances between different points of applications of power, not only the question of utilization but also that of transmission becomes of importance. Three forms of power, steam, compressed air and electricity, are to be considered. Originally, of course, the power must come from coal or water power.

Choice of System. The choice of the best system of hoisting in any particular case is the result of considering carefully many different factors. Most important among these is the cost of operation and installation. In this regard the location of the power house to ensure the best and cheapest supply of fuel and water is of primary importance. It is highly desirable to group a large number of mines, so that they may be supplied from one power station. As a rule, mining shafts are not well-situated as regards the supply of coal and water, so that it is usually necessary to transmit power for some distance, and this is best done by electricity. The problem then becomes one of the utilization of power, or the generation of electricity by means of steam turbines or gas engines. In metal mining, fuel is usually expensive and often but little water is available at the mines, so steam hoisting engines are generally run non-condensing. Where the reverse is the case, it is in most cases cheaper to transmit electricity to the mines than to pump condensing water there.

Efficiency of Steam Plants. Steam hoisting plants are known to be very inefficient, but the exact figures are usually difficult to obtain. With non-condensing engines and an extremely intermittent load on both engines and boilers, the economy necessarily is very poor. Steam engines must be designed for starting conditions, where they take steam under full stroke, and this necessitates their running with an early cut-off when hoisting. With a number of plants close together, there is no way of returning power to the line or of smoothing the peaks of the load. It is impossible, when a steam

engine is used, to store power in retardation. There is also a limit in the depth at which steam engines can be satisfactorily placed, and their installation in mines is thus very undesirable.

Advantages of the Electric System. In many cases the electric system of hoisting has advantages which give it decided preference. The power house may have the most favorable location—power may be taken from some existing transmission system, or a water power may be developed for the purpose. Power may be centrally generated at the highest efficiency, and distributed over a large area. Electricity is most easily applied to all work on both the surface and the interior of mines. One of its greatest advantages in practice is the ease of making extensions to the development. With one station and many individual loads, an overlapping of peaks occurs, and a consequent reduction in boiler and generating capacity is effected. The cost of installation and operation is much reduced, a much improved load factor results and fewer operators are required.

For underground pumping and tramming, and where the hoists are located in the mine, electricity has every advantage. For use with electric hoists, safety devices have been developed which prevent over-winding and which also limit the acceleration. Power can be returned to the system in braking and in lowering unbalanced, and a much higher fuel economy can be obtained.

The use of hoists operated by compressed air has long been considered and at present some installations are being made. With the usual features of such equipment it is necessary to cool the air during compression and to re-heat it before use. In general, serious questions would arise concerning the efficiency of any system using compressed air for hoisting. The efficiency of an electric hoisting system is not open to question, and can be figured with exactness. There is no reason why advocates of compressed air systems should not be required to give the same guarantees and to state positively just what efficiency they are sure of obtaining.

Motor Characteristics

Large electric mine hoists are almost universally driven either by shunt-wound direct-current motors or polyphase induction motors, the characteristics of which especially adapt them to meet the peculiar conditions imposed. While in many of their characteristics these two types of motor are similar, they differ

widely in others, which are of more or less importance depending upon special conditions of individual cases.

Fig. 1 gives the efficiencies, currents and speeds of the direct-current shunt motor at various loads for constant impressed voltage, and Fig. 2 gives similar curves for the induction motor, to which is added the power-factor curve. By reference to these curves it will be seen that the free-running speed of each motor is limited, and that the variations in speed with changes in load are small; that each becomes a generator when driven above speed, and may therefore be used as a brake when lowering unbalanced loads, returning power to the supply system; that the efficiencies of both when operating either as motor or generator are virtually the same for corresponding loads.

The speed of the shunt motor for a given load may be varied between standstill and full speed either by changing the potential of the supply system, or by inserting resistance in series with its armature. However, because of the inefficiency of this latter method of control, it is seldom, if ever, used in connection with large hoist motors. The only practical method of obtaining a similar variation in the speed of an induction motor is by changing the amount of resistance connected in its armature circuit. Fig. 3 shows the efficiencies of the shunt motor at various speeds when exerting full-load torque, the variations in speed being obtained by voltage control, and the efficiencies of the induction motor being under similar conditions, except that in this case the variations in speed are obtained by armature rheostatic control. By reference to the curves it will be seen that for a given torque, the efficiency curve of the shunt motor at reduced speeds resembles that for the constant speed motor at reduced loads, while the efficiency curve of the induction motor is a straight line between full-load efficiency and speed, and zero efficiency and speed. From this it follows that, for a given value of torque, the input to the shunt motor at reduced speeds, except for very low speeds, is approximately proportional to the speed, while the input to the induction motor is constant and independent of the speed. It will also be noted that the shunt motor may be driven as a generator at reduced speeds, while the induction motor can be made to generate only when driven above synchronous speed. Where the conditions are such that it is desirable to drive the hoist at reduced speeds for any considerable lengths of time, the efficiency of the induction motor drive may be improved by using a motor designed for two speeds,

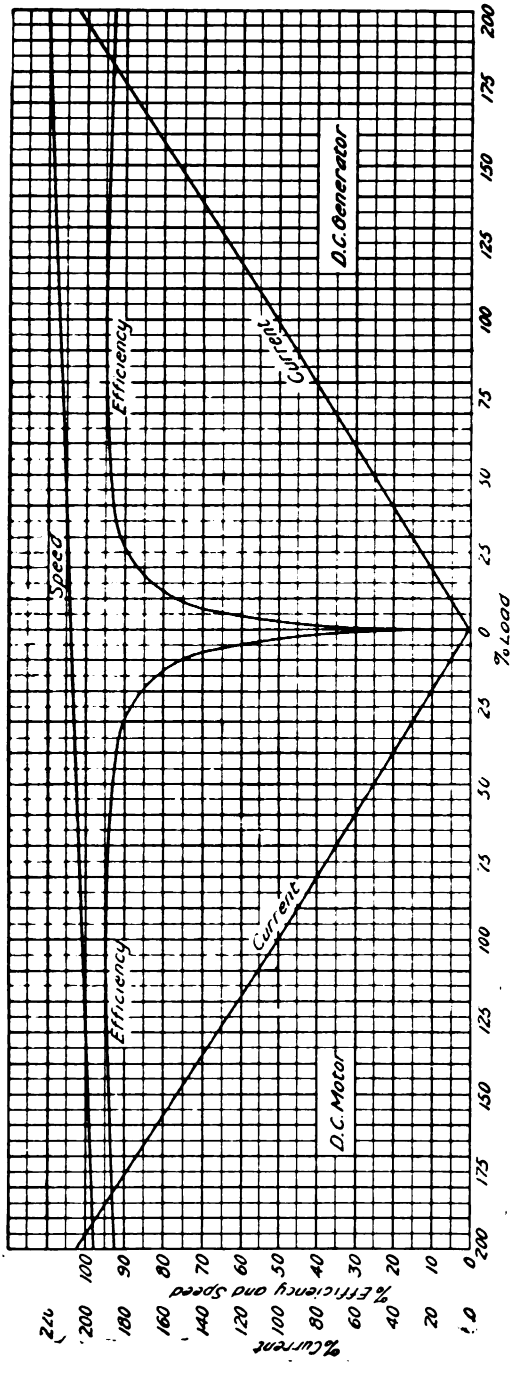

Speed
Efficiency
Current
D.C. Generator
Efficiency
Current
D.C. Motor
% Load
200 175 150 125 100 75 50 25 0 25 50 75 100 125 150 175 200
% Efficiency and Speed
100 90 80 70 60 50 40 30 20 10 0
% Current
200 180 160 140 120 100 80 60 40 20 0

FIG. 1

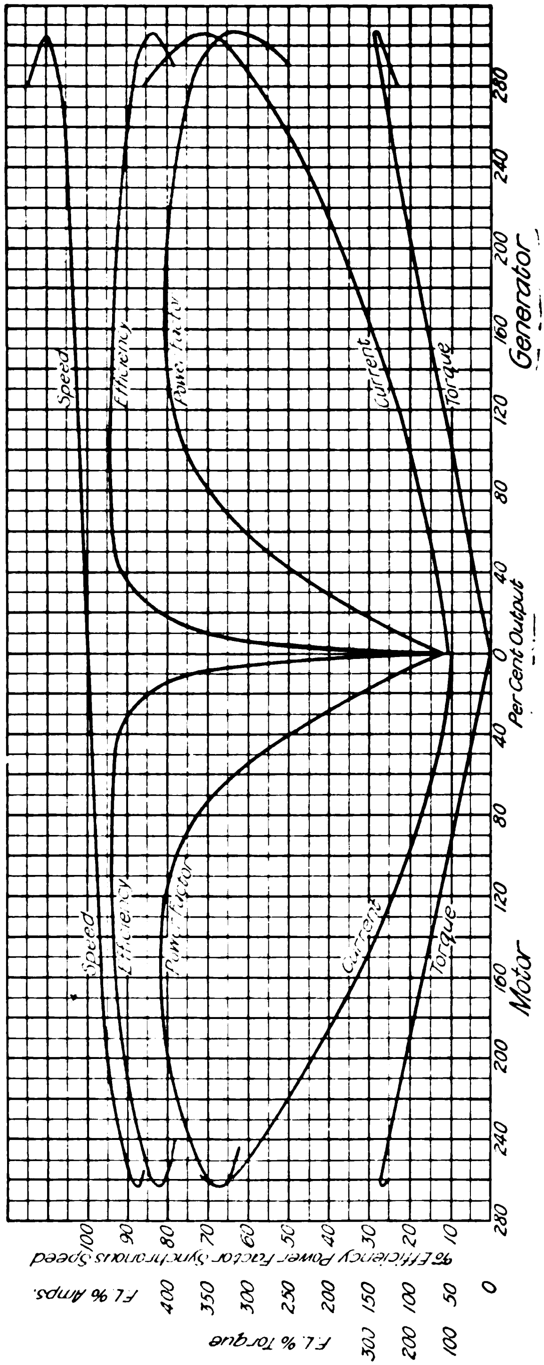

Speed
Efficiency
Power Factor
Current
Torque
Generator
Motor
Per Cent Output
280 240 200 160 120 80 40 0 40 80 120 160 200 240 280
% Efficiency Power Factor Synchronous Speed
100 90 80 70 60 50 40 30 20 10
F.L. % Amps.
400 350 300 250 200 150 100 50 0
F.L. % Torque
300 200 100

FIG. 2

or by using a concatenated set, but the advantages gained are seldom sufficient to offset the increased first cost and the necessary complication of the control.

The number of poles, and therefore the diameter of an induction motor, is determined by its speed and the frequency of the supply system, the number of poles varying inversely as the speed for a given frequency, while the frequency of the e.m.f. generated in the armature of a direct-current motor is independent of the supply system. While this is of little importance in the designing of motors of moderate speed for gearing,

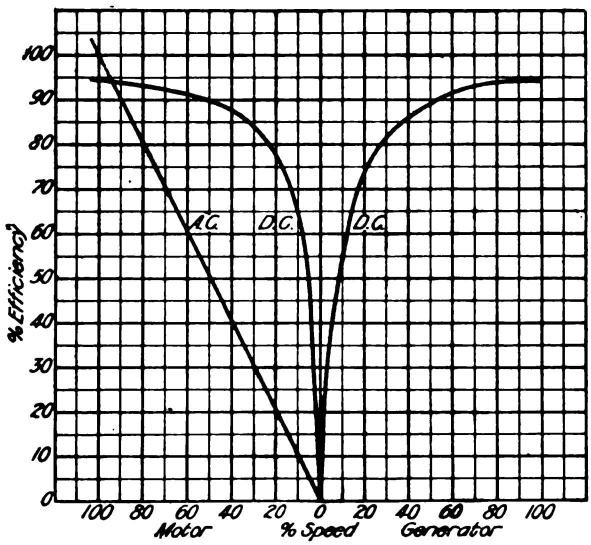


Fig. 3

it permits of a better proportioning of the length and diameter of shunt motors of very slow speed than is possible in the case of similar induction motors for direct connection, especially where the frequency of the supply system is 60 cycles.

As pointed out, the efficient speed control of the shunt motor is only obtained by varying the voltage of the supply system, the usual method being to provide a generator for each motor and varying the generated potential. As mine shafts are usually scattered over a considerable area, and the conditions in close proximity to the shafts are not such as to permit of the economical generation of electric power, the central electric station is

usually placed at a considerable distance from the hoists, the power is generated and transmitted to the mines as alternating current and is then transformed at each shaft into direct current by motor-generator sets. The losses caused therein must be charged against the shunt motor when comparing its efficiency with that of the induction motor, which may be connected either directly or through highly efficient static transformers with the alternating-current distributing system. The torque and current for the two types of motor are approximately proportional within their operating limits.

Hoist Load Diagrams

Before discussing the various systems of electric hoisting it will be well to consider the nature of a mine-hoist load. Mine hoists may be divided into six types, depending upon whether the rope is wound on a reel, a cylindrical drum, conical drum, cylindro-conical drum, Whiting drums, or carried over a Koepe disk, the choice of any particular type depending largely upon the depth of shaft, the maximum permissible hoisting speed, the location of the hoist with respect to the shaft, the number of levels which are being worked simultaneously, and whether or not the shaft conditions permit the use of a tail rope.

The hoists are generally operated in balance, that is, the weight of the skip (or cage and car as the case may be) carrying the ore, is balanced by a similar empty skip which is lowered in a second compartment simultaneously with the hoisting of the loaded skip in the first, the loaded skip being dumped at the top and the empty one loaded at the bottom, and the cycle then repeated. To permit of adjustment of the length of the ropes for hoisting from different levels, it is customary to use two reels or drums mounted on the same shaft, one being keyed to the shaft and the other being driven by it through some form of clutch. The length of rope on the Koepe disk hoist or the Whiting hoist cannot conveniently be adjusted for different levels except within very small limits.

For the purpose of comparing the load diagrams of the different types, each hoist is assumed to lift 8000 lb. of ore in a skip weighing 5000 lb., from a vertical depth of 2500 ft. at an average speed of 2000 ft. per min., allowing 20 sec. for acceleration and 15 sec. for retardation. The rope for the reel hoist is assumed to be 5 inches x $\frac{1}{2}$ inch, weighing $4\frac{1}{2}$ lb. per ft. and that for the others $1\frac{3}{8}$ inches round steel rope weighing 3 lb. per ft.

Reel Hoist. As its name indicates, the reel hoist consists of two large reels on which the rope supporting the skips is wound in a spiral, the distance between the flanges of the reels being approximately equal to the width of the flat rope used. The reel hoist is generally used where it is necessary to place the hoist very close to the shaft. As the minimum diameter of the reel, usually from 5 to 8 ft., is limited, and as its maximum diameter is determined by the thickness and length of the rope, the depth from which hoisting may be done at a given average speed by reel hoists is governed by the maximum permissible hoisting speed.

Let us assume that the loaded skip is at the bottom of the shaft and that the empty skip is at the top. Then the length L_a of the ascending rope with the skip at any point in the shaft may be obtained from the equation

$$L_a = D - 2 \pi a r_1 - \pi a^2 b$$

and its moment, M, about the drum shaft by

$$M_1 = (D - 2 a \pi r_1 - \pi a^2 b) r n \cos \phi$$

in which D = depth of shaft; b = thickness of the rope; n = the weight of the rope per foot; r_1 = the radius of the rope on the reel when the skip is at the bottom of the shaft; a = the number of turns of the reel in raising the skip from the bottom of the shaft to the point in question; $r = r_1 + a b$ = the radius of the rope on the reel after a turns and ϕ = the angle which the shaft makes with the vertical.

The moment of the ascending load is obtained from the equation:

$$M_2 = (W_1 + W_2) r \cos \phi$$

where W_1 = the weight of the skip (or cage and car as the case may be) and W_2 = the weight of the ore.

Plotting M_1 and M_2 against revolutions of the reel, we obtain curves M_1 and M_2 in Fig. 4.

The moments M_1' of the descending rope may be plotted from the values obtained for the ascending rope, by simply assuming the center of coördinates in Fig. 4 transferred from the left to the right side of the curves, turn No. 10 of the descending load corresponding to turn No. 81 of the ascending load, etc.

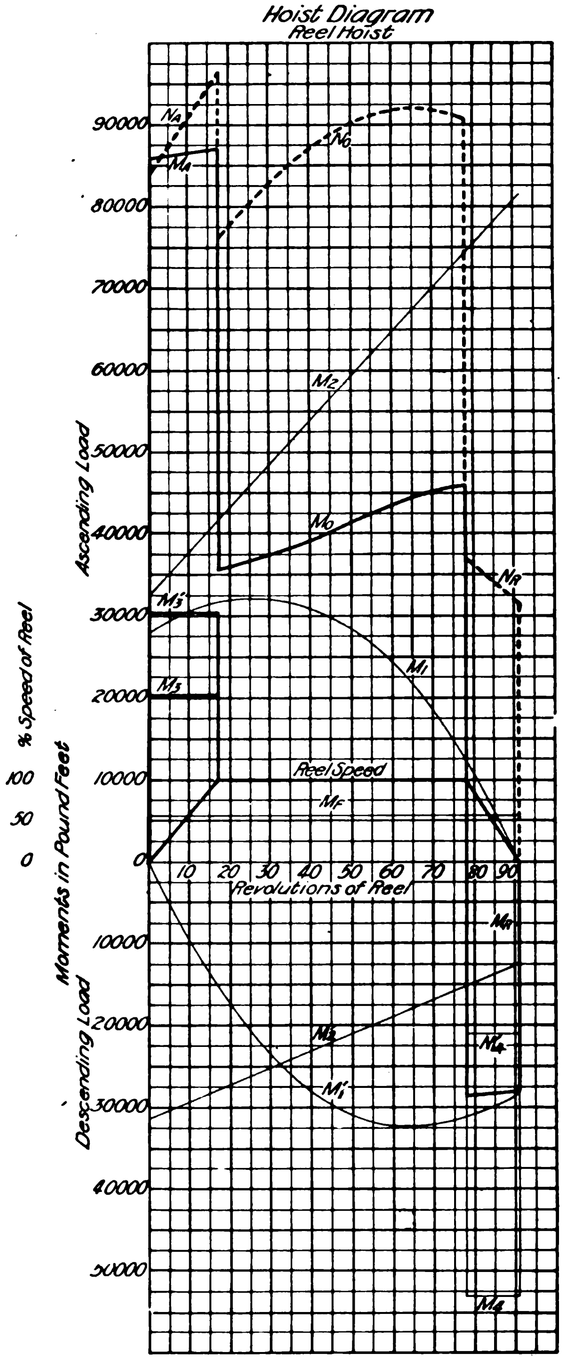

Hoist Diagram
Reel Hoist
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
10000
20000
30000
40000
50000
Ascending Load
Descending Load
Moments in Pound Feet
% Speed of Reel
100
50
0
10 20 30 40 50 60 70 80 90
Revolutions of Reel
Reel Speed

Fig. 4

Similarly, the moment M_2' of the descending load may be obtained by substituting W_1' for $W_1 + W_2$ in the equation for M_2, and plotting as directed for the descending rope.

Moments M_1' and M_2' are plotted below the reference line, since their tendency to rotate the reel is opposed to that of M_1 and M_2.

Denoting the moment of the total friction and windage by M_f the resultant moment M_0 of the ascending ore skip, rope and friction and the descending skip and rope is expressed by $M_0 = M_1 + M_2 - M_1' - M_2' + M_f$, which is the moment of the force, or the torque which must be applied to the reel to raise the ore.

The moment M_f of the friction is extremely difficult to obtain, and varies considerably with local conditions, but it is usually assumed to be approximately 15 per cent of the average value of $M_1 + M_2 - M_1' - M_2'$.

During the period of acceleration, a force additional to that required to raise the load and overcome friction, must be applied to the reel for accelerating the reels, ropes, etc. Assuming a uniform rate of acceleration, the moment M_3 of the force necessary for accelerating the ascending load, rope and one reel and clutch, may be determined from the equation

$$M_3 = \frac{\Sigma W S}{g t_a} p$$

where ΣW = the sum of the weights of the skip, ore, rope, one reel and clutch, and sheave reduced to a common radius of gyration p; S = the speed at the end of the radius of gyration in feet per second at the end of acceleration; g = 32.2, and t_a the time of acceleration in seconds.

Similarly, the moment M_3' of the force required for accelerating the descending skip, rope, etc., may be found from the equation

$$M_3' = \frac{\Sigma W' S}{g t_a} p$$

where $\Sigma W'$ = the sum of the weights of the descending skip, rope, reel, and sheave reduced to the radius of gyration p.

At the end of the cycle all of the energy stored in the revolving parts of the hoist and its load is returned as the load is brought to rest. The moments M_4 and M_4' of the retarding forces may

be found from the expressions for M_3 and M_3', respectively, substituting for ΣW and $\Sigma W'$ the corresponding weights at the beginning of retardation.

Throughout the cycle there is a gradual increase in the speed of the ascending ore skip and unwound rope, and a similar decrease in the speed of the descending skip and unwound rope, but the accelerating and retarding forces are small and their moments may be neglected.

The resultant moments M_A and M_R during the periods of acceleration and retardation respectively are expressed by the equations

$$M_A = M_1 + M_2 + M_3 + M_3' + M_F - M_1' - M_2'$$

$$M_R = M_1 + M_2 + M_F - M_1' - M_2' - M_4 - M_O'.$$

M_A, $M_O M_R$ of Fig. 4 is the resultant moment diagram for balanced hoisting under the conditions assumed.

While hoists are generally operated in balance, it is frequently necessary to run them unbalanced for short periods while repairs are being made. The moment diagram $M_A M_O M_R$ for unbalanced hoisting is obtained from the equations

$$M_A = \frac{M_F}{2} + M_1 + M_2 + M_3$$

$$M_O = \frac{M_F}{2} + M_1 + M_2$$

$$M_R = \frac{M_F}{2} + M_1 + M_2 - M_4$$

The speed of the ascending or descending skips may be obtained from the equation

$$V = 2 \pi r S$$

Cylindrical Drum Hoists. The cylindrical drum hoist is the type almost universally used for comparatively shallow shafts, and very frequently for the deeper ones. It consists of two

cylindrical drums, upon which the rope is wound in one or more layers, the diameters of the drums varying from 5 or 6 feet to 25 feet.

The general equations for determining the several moments which make up the reel moment diagram, are made applicable to the cylindrical drum hoist by simply making b equal to zero. The moment diagrams for the cylindrical drum hoist are shown in Fig. 5. The notches in the diagram are due to the increase in diameter of the drum with each layer of rope.

By reference to the figure, it will be seen that M_0, the resultant moment of the ore skips and ropes, is very large at the first part of the cycle and decreases very rapidly toward the end of the cycle, this being due to the influences of M_1 and M_1', the moments of the rope. This difference in M_0 at the beginning and at the end of the cycle, increases with the depth of the shaft, the weight of ore per trip remaining constant; or for the same depth of shaft with reductions in the weight of ore hoisted, M_0 often becoming partially zero or negative toward the end of the cycle. The harmful effect of this extreme variation in M_0 is two-fold. First, the engine must be larger than otherwise necessary in order to start the hoist, and second, it operates at an inefficient cut-off at the end of the cycle. To reduce this variation in M_0 at the beginning and at the end of the cycle, the conical drum has been introduced.

Conical Drum Hoists. In the conical drum hoist, the ropes are wound in single layers on two large cones, the rope being wound from the small to the large end of the cone. The method of determining the moment diagrams is the same as for the reel hoist, making b equal to the increase in the radius of the cone for one turn of the rope. By reference to Fig. 6, which shows the moment diagrams for the conical drum hoist, it will be noted that the unbalancing due to the rope in the shaft, has been entirely compensated for; in fact M_0 actually increases toward the end of the cycle. By varying the angle of the cone, M_0 may be made to increase or decrease toward the end of the cycle, or remain practically constant.

Cylindro-conical Drum Hoist. The use of the conical drum as was the case with the reel, is limited to comparatively shallow shafts. For depths below which the use of the conical drum is impracticable, it is necessary to compromise, using a drum which as its name indicates, is a combination of cone and cylinder. The rope is wound from the small end of the cone over the

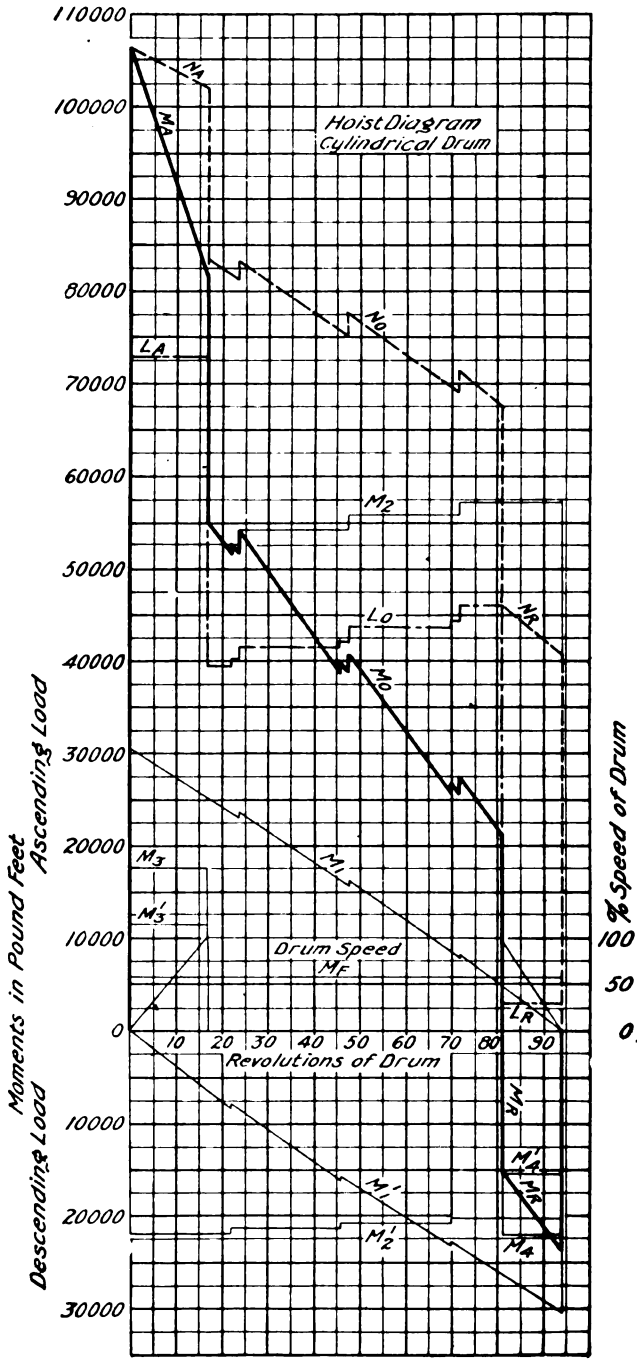

Hoist Diagram
Cylindrical Drum
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
10000
20000
30000
Moments in Pound Feet
Ascending Load
Descending Load
% Speed of Drum
100
50
0
10 20 30 40 50 60 70 80 90
Revolutions of Drum
Drum Speed
M_F
N_A
M_A
L_A
N_0
M_2
L_0
N_R
M_0
M_1
M_3
M_3'
L_R
M_R
$M_A' + M_R$
M_4
M_1'
M_2'

Fig. 5

conical part of the drum in a single layer, then onto the cylindrical portion in one or more layers, depending upon the length of the rope. The load diagram is readily obtained by dividing the cycle into two parts, and treating the conical and cylindrical

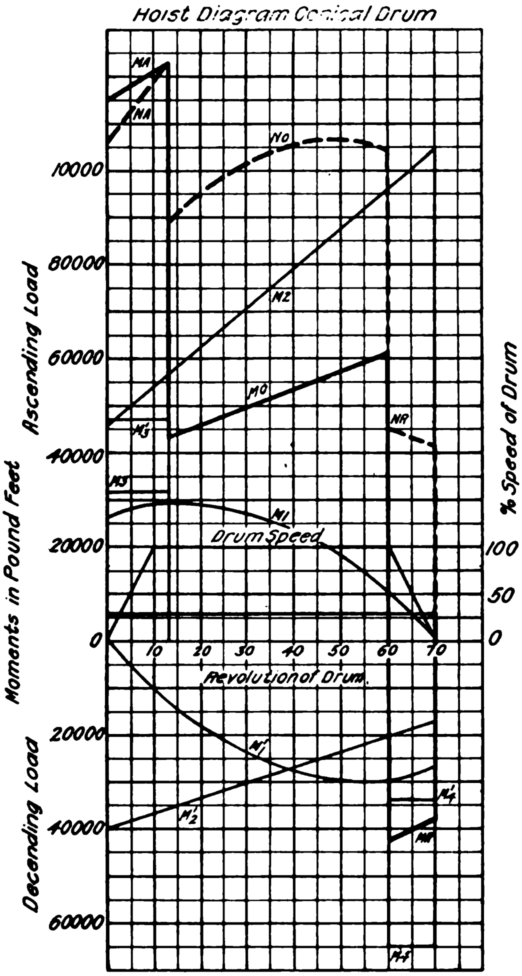


FIG. 6

portions of the drum separately, determining the moments over the conical part as directed for the conical drum hoist, and over the cylindrical portion as directed for the cylindrical drum hoist. The moment diagram, Fig. 7 shows very clearly the effect of the

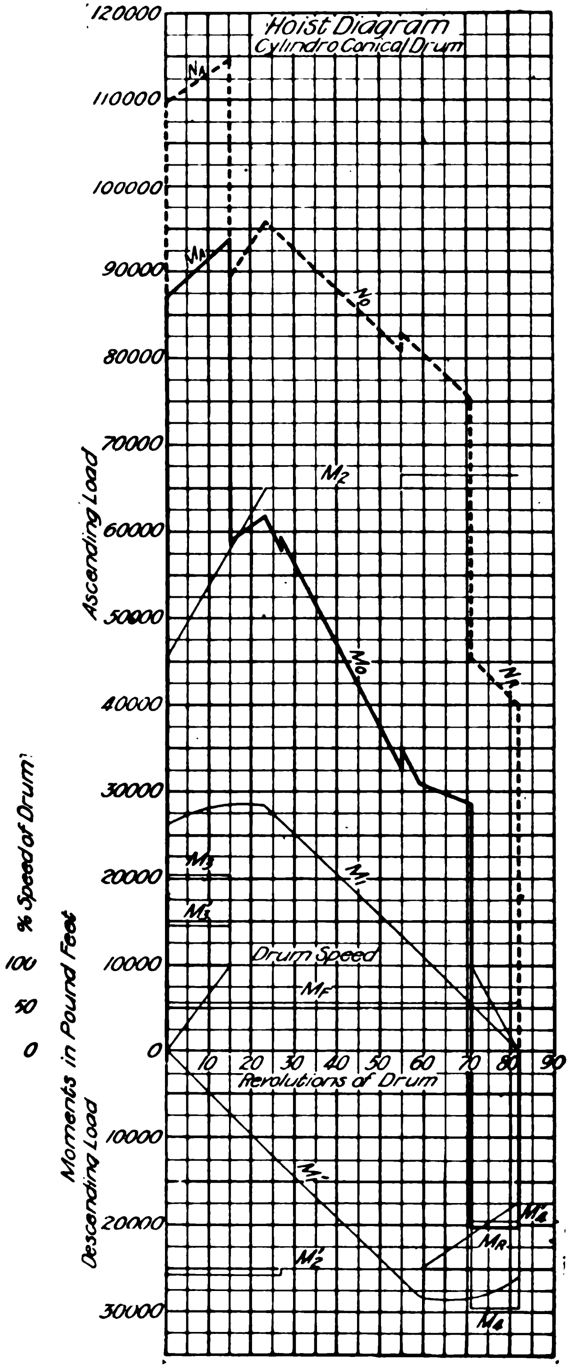

Hoist Diagram
Cylindro Conical Drum
Ascending Load
Descending Load
Moments in Pound Feet
% Speed of Drum
Revolutions of Drum
Drum Speed
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
100
50
0
10 20 30 40 50 60 70 80 90
M_F
M_1
M_2
M_3
M_A
M_R
N_0
N_A

FIG. 7

conical portion of the drum, although the improvement in shape of the moment curve, over that for the cylindrical drum, is not so marked as it is for greater depths of shaft.

Tail Rope. The skips or cages are sometimes connected by a tail rope which passes over a sheave at the bottom of the shaft, thus making the total weight of the ascending and descending ropes the same, independent of the location of the cages in the shaft. The effect of the addition of the tail rope is shown in Fig. 5, L_A, $L_0 L_R$ being the moment diagram resulting from the addition of a tail rope to the cylindrical drum hoist, which otherwise remains unchanged.

Koepe Disk Hoist. A type of hoist very common throughout Europe, but which has never been installed in America, is that known as the Koepe disk hoist, which consists simply of a large grooved wheel over which the rope passes once, the friction between the disk and the rope being sufficient to move the cages or skips in the shaft. Hoists of this type are always operated in balance and a tail rope is used with them. They are not well adapted for hoisting from several levels, because of the fixed position of the cages or skips, which can be changed only with difficulty to correspond with different levels. The moment diagram of this type of hoist is similar to that of the cylindrical drum hoist with a tail rope, except that b_0 will be a horizontal line, the notches due to the different layers of rope on the drum not being present in the Koepe disk hoist diagram.

Whiting Hoist. In order to increase the arc of contact between the rope and the wheel, Mr. Whiting substituted two narrow drums for the Koepe disk, the drums being placed one directly in front of the other, and the rope being passed four or five times over both drums. For the purpose of taking up the stretch in the rope and making small adjustments of the cages, one side of the rope is carried back over a moveable sheave mounted on a carriage resting on rails, the adjustments being made by changing the position of the carriage. Whiting hoists are always operated in balance and seldom if ever without a tail rope. The moment diagram is exactly similar to that of the Koepe disk hoist.

The moment diagrams may be transformed into horse-power time diagrams by the use of the equation

$$\text{horse power} = \frac{2 \pi M R}{550}$$

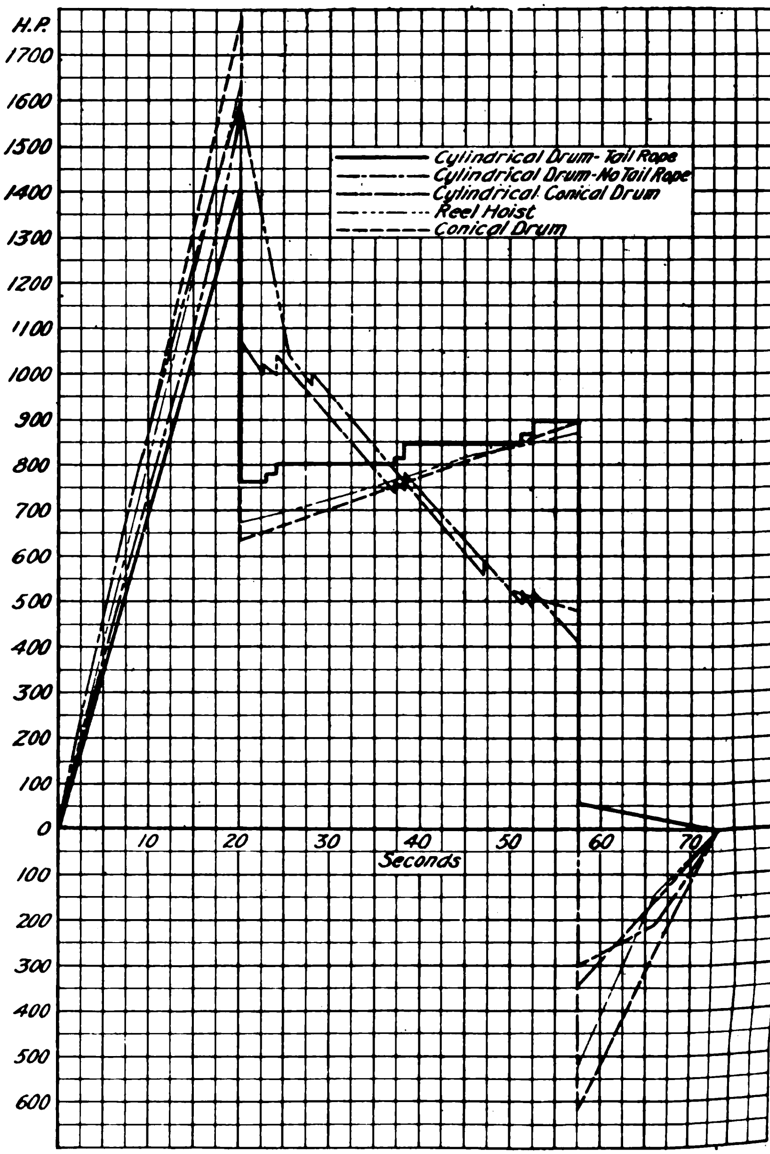

H.P.
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
400
500
600
10
20
30
40
50
60
70
Seconds
Cylindrical Drum-Tail Rope
Cylindrical Drum-No Tail Rope
Cylindrical Conical Drum
Reel Hoist
Conical Drum

FIG. 8

where M = the moment in pound feet and R = revolutions of the drum per second.

The horse-power diagrams corresponding to the moment diagrams of Figs. 4, 5. 6 and 7 are shown in Fig. 8, the curves for the balanced hoisting only being shown. Attention is called to the difference in the heights of the peaks during acceleration, the magnitude of these peaks having an important influence on the design of a motor for driving the hoist, its efficiency for the complete cycle, and the cost of power, if power is purchased.

Systems of Electric Hoisting

The early application of electric power to mine hoisting was confined to small hoists, moving cars on inclines or hoisting light loads vertically from comparatively short depths. The complete success of these early installations led to the use of electric motors for winding from greater depths, until to-day ore is hoisted by electric power from some of the deepest mines in the world. The use of electric motors for driving the hoists, permits of the substitution of a large central electric generating station, which operates at a comparatively high load factor and which is placed where the conditions are more favorable for the economical development of power than they are at the mines, in place of isolated steam plants located at the shafts where condensing water is seldom available and where fuel is often expensive. The speed of the hoist motor when lowering unbalanced loads is automatically limited to approximately the hoisting speed. Safety devices in the nature of limit switches can readily be applied to prevent over-winding, and the acceleration of the hoist is made automatic; all of which tend to minimize the possibility of accident resulting from carelessness on the part of the operator. Not only is the speed limited when lowering unbalanced, but a large part of the energy, which with the steam-driven hoist is absorbed by the brakes, is returned to the electric supply system, thereby improving the economy of operation and reducing the wear on the mechanical brakes.

Many systems of electric hoisting have been proposed, each with the view of meeting some peculiar condition, or eliminating some real or apparent objection in the others, but virtually all the installations are confined to four systems, shown in Figs. 9, 12, 15 and 20. To assist in the comparison of the several systems, the authors have assumed a hoisting cycle, for both balanced and unbalanced operation, and have calculated the

current and power taken by each system under the conditions assumed.

The first and simplest system is shown in Fig. 9, and consists of a polyphase induction motor, direct connected or geared to the hoist drum. The speed of the motor is controlled by a variable resistance in its rotor circuit, which, because of the magnitude of the currents, involved, is usually some form of water rheostat. A common type of water rheostat consists of a tank, usually of boiler plate riveted together, and divided into two compartments; one the rheostat proper, and the other a cooling tank. The electrolyte is pumped from the cooling tank

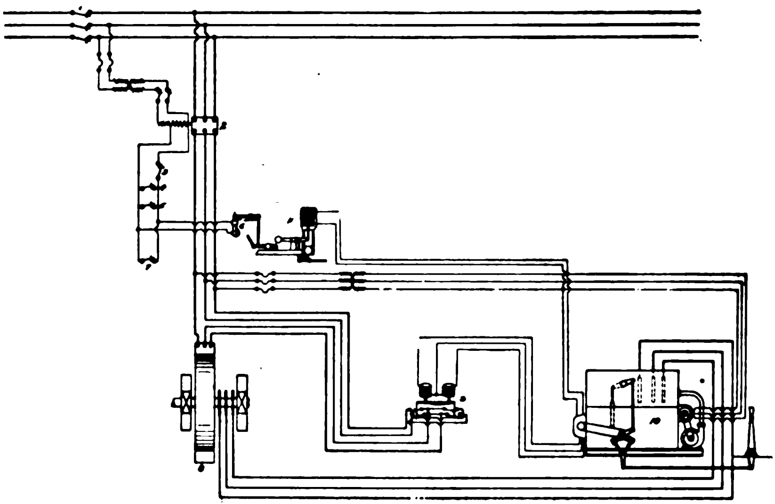


FIG. 9.—No. 1–2 Line switches. No. 3–4–5–6–7 safety switches for preventing overwinding and stopping the hoist, No. 8 hoist motor, No. 9 reversing switch, No. 10 liquid controller, No. 11, automatic brake.

into the rheostat proper, entering at the bottom of the rheostat and flowing out over the top of an adjustable weir, back into the cooling tank. The resistance in the rotor circuit is varied by changing the height of the electrolyte in the rheostat proper by means of the adjustable weir. The electrodes are usually thin iron plates hung on insulators, all phases being in the same compartment. At least one electrode per phase is of extra length, extending below the lowest level of the liquid, in order to prevent the rotor circuit from being opened. The most common form of electrolyte is a simple salt solution. The control of the rheostat is by means of a lever located on the operating stand.

Figs. 10 and 11 give the current and power curves for one complete balanced and unbalanced cycle, respectively. Frequently the cage is moved a few feet only, to obtain a proper setting of the cage or skip. The power taken for such short movements is shown by the right hand curves of Fig. 10. In these curves, as well as in those which apply to the other systems,

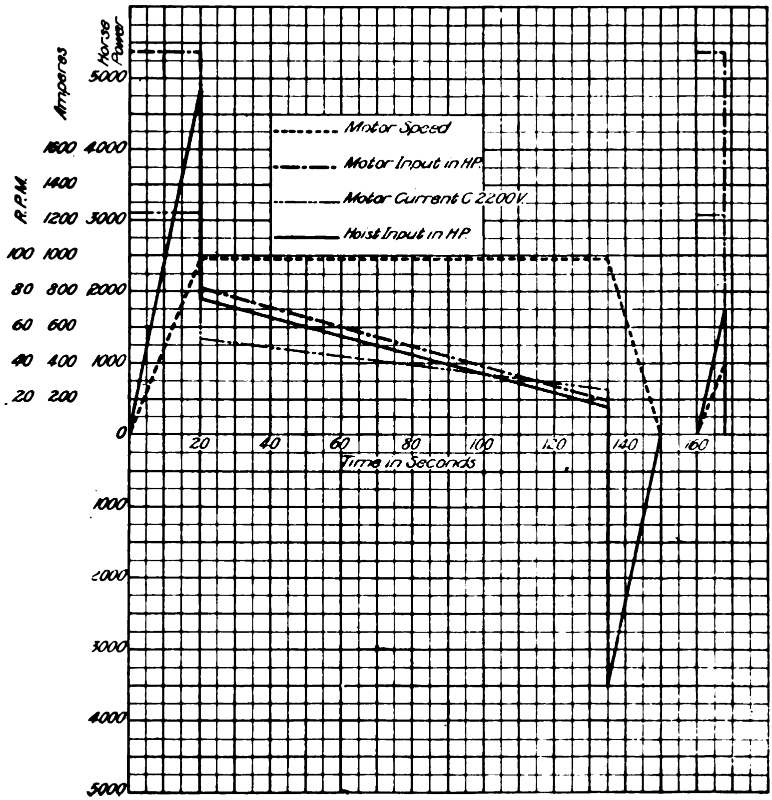


Fig. 10

power delivered to the hoist is shown above the reference line and that returned by the hoist, below it.

By reference to the curves, it will be noted that the horse power and current taken by the motor are constant during the period of acceleration; that the efficiency for this period is very low, approximately 45 per cent; that no power is returned to the supply system during the period of retardation, and that the

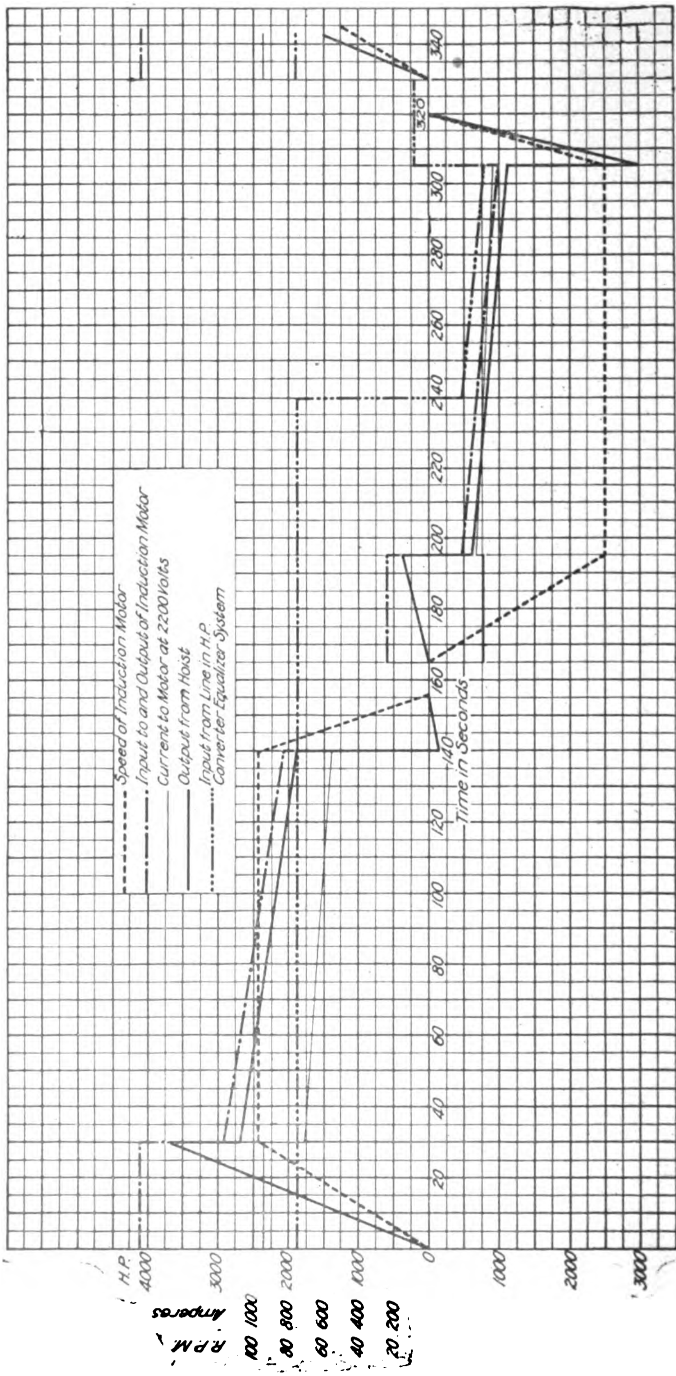

Speed of Induction Motor
Input to and Output of Induction Motor
Current to Motor at 2200 Volts
Output from Hoist
Input from Line in H.P.
Converter Equalizer System
Time in Seconds
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
H.P.
4000 3000 2000 1000 0 1000 2000 3000
Amperes
1000 800 600 400 200
R.P.M.
100 80 60 40 20

FIG. 11

power consumption for small movements of the cage or skip is very large. On the other hand, the efficiency during the period when the hoist is running at full speed is high, approximately 90 per cent, and no power is consumed while the hoist is at rest.

The efficiency over the complete cycle obviously decreases rapidly with a decrease in the time during which the hoist is driven at full speed. It follows from this that when hoisting is to be done from several levels, the efficiency at the maximum

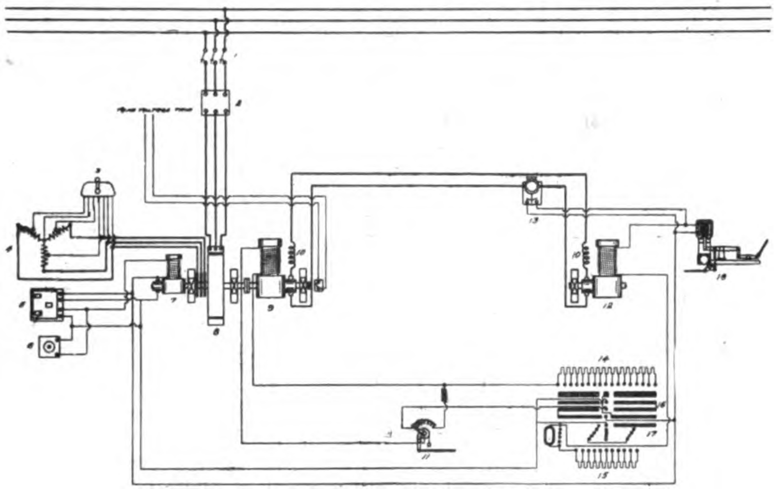


FIG. 12.—No. 1-2 line switches; No. 3-4 controller and resistance, induction motor; No. 5-6 Tirrill regulator and rheostat for exciter; No. 7-8-9 motor generator set; No. 10, commutating pole and compensating field winding; No. 11 safety device; No. 12 hoist motor; No. 13 circuit breaker; No. 14-15-16-17 rheostat and controller for generator and hoist motor; No. 18 automatic brake solenoid.

depth alone cannot be used as a basis for comparing the hoist driven by the induction motor with other systems. The efficiency of the cycle increases with an increased rate of acceleration, from which it follows that an induction motor for hoisting should be designed for a high maximum output to permit of a rapid acceleration.

The power returned to the system when lowering the empty skip unbalanced is shown by the right hand curves of Fig. 11. A comparison of the power taken by the motor in hoisting the

loaded skip with that returned when it is lowered empty, shows that approximately 20 per cent of the power taken for hoisting is returned in lowering.

The second system is that shown in Fig. 12. In this system the hoist is driven by a direct-current shunt-wound motor receiving power from the alternating-current supply system through a synchronous or induction-motor-generator set. The hoist motor

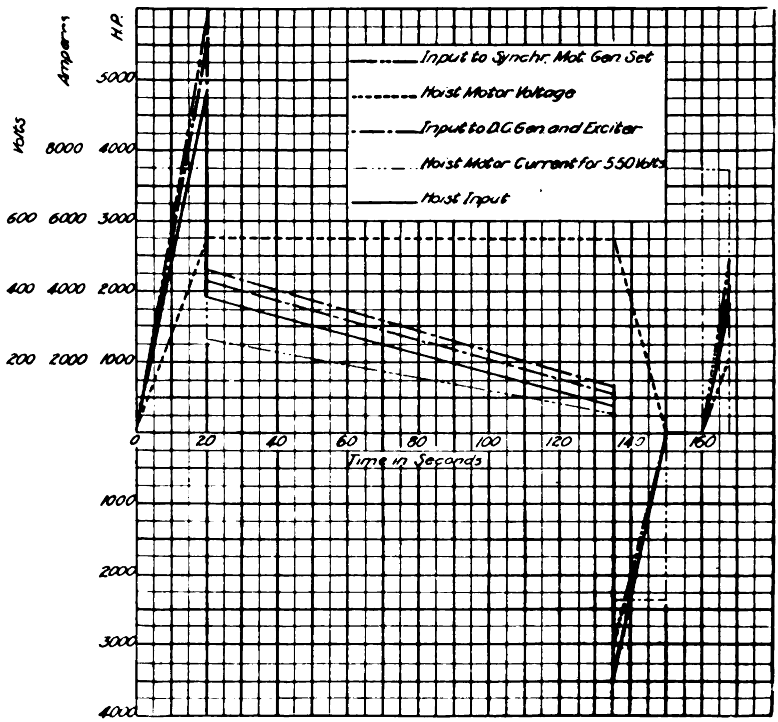


FIG. 13

is controlled by varying the voltage of the generator, which is separately excited, one generator being used for each motor.

The power and current curves for the balanced and unbalanced cycle, are shown in Figs. 13 and 14 respectively. These curves show that the power consumed during acceleration, is much smaller than for the induction hoist motor, the efficiency then being approximately 80 per cent, and that a considerable part of the energy stored in the revolving parts of the hoist is returned

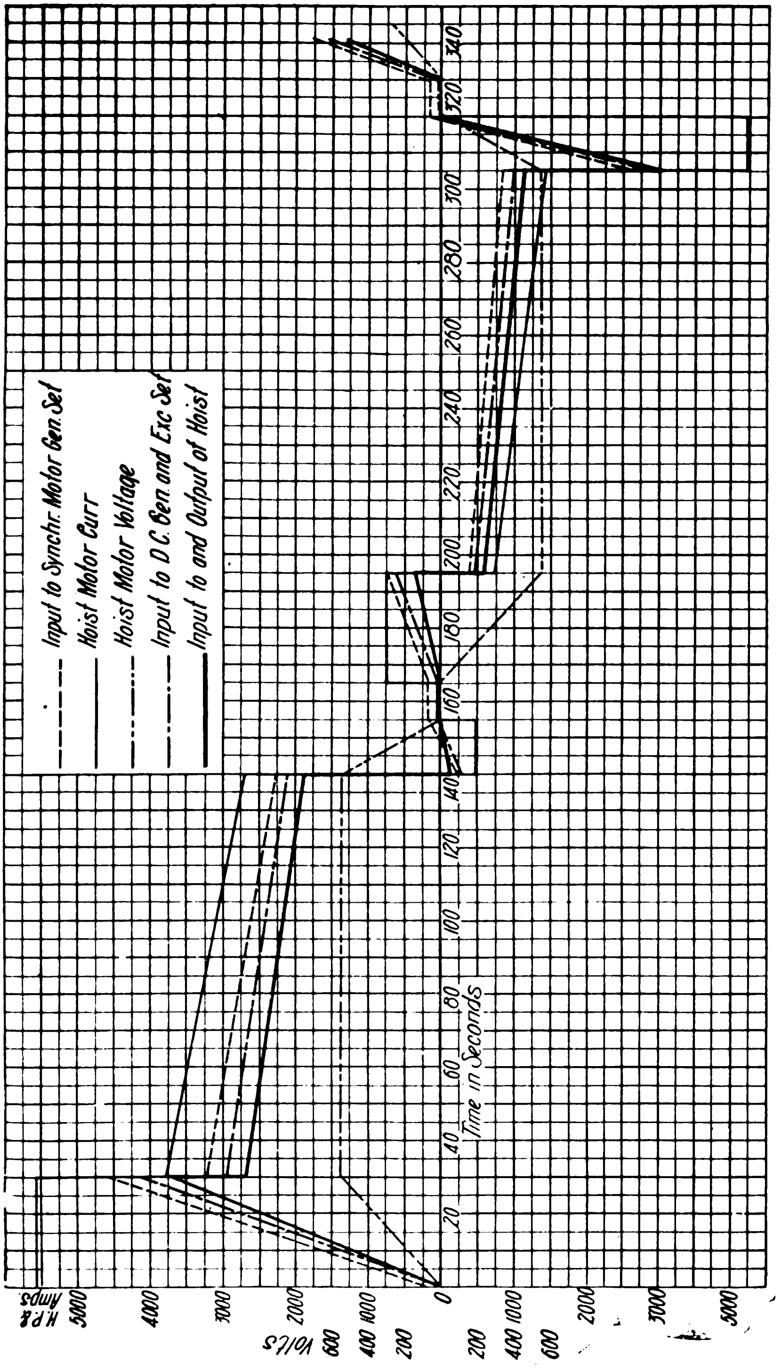

Input to Synchr. Motor Gen. Set
Hoist Motor Curr
Hoist Motor Voltage
Input to D.C. Gen. and Exc. Set
Input to and Output of Hoist
Time in Seconds
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
H.P. & Amps
5000
4000
3000
2000
1000
Volts
600
400
200

Fig. 14

to the supply system as the hoist is brought to rest. On the other hand, the efficiency when the hoist motor is running at full speed, is lower than that for the induction hoist motor, being approximately 82 per cent, and the losses of the motor-generator set when running light, must be supplied during the time when the hoist is at rest. In view of the fact that a mine hoist is idle 50 per cent or more of the time under ordinary conditions, this is an item in the total power consumption which cannot be neglected. It follows from what has been stated, that the advantage of the direct-current hoist motor over the induction hoist motor in the efficiency through the complete cycle is greatest for short lifts, in which case the period of acceleration is a large percentage of the total cycle and the time during which the hoist is idle is a minimum.

By reference to the curves of Fig. 14 it will be seen that approximately 30 per cent of the power consumed in hoisting the ore unbalanced is returned to the system when the skip is lowered.

No definite rule can be laid down by which a choice can be made between the two systems, each having advantages and disadvantages peculiar to itself which have a more or less important bearing on the choice, depending upon the special conditions of the individual problem. The first system has the advantages of low first cost and simplicity, but is often at a disadvantage in respect to efficiency. On the other hand, the higher efficiency of the second system is frequently more than offset by its increased first cost and its greater cost of maintenance.

Both systems are open to the objection that the power drawn from the supply system fluctuates between very wide limits during each cycle, generally reaching a maximum during acceleration, becoming negative during retardation for the second system, zero, or practically so, at the end of the cycle, and negative when lowering unbalanced for both systems. The effect of this wide fluctuation in the load during each cycle, is to seriously impair the voltage regulation of the supply system unless its capacity is large as compared with the fluctuations, or unless the number of hoists driven from the same system is sufficient to produce a fairly uniform load, which is seldom the case for a mine power system. Also, if power is purchased, the price is usually made up of two components; one based on the total kilowatt hours consumed, and the other on the maximum demand.

It therefore becomes necessary in most cases to provide some means whereby power may be taken from the supply system

and stored during the portion of the cycle when the demand for power is less than the average, and returned when the demand exceeds the average.

Fig. 15 shows such a system, the third, in which advantage is taken of the low first cost and efficiency of the fly-wheel as a means for storing and returning large quantities of power for short intervals. This system is similar to the second, except for the addition of a fly-wheel to the induction motor-generator set, and an automatic regulator for varying its speed. In its

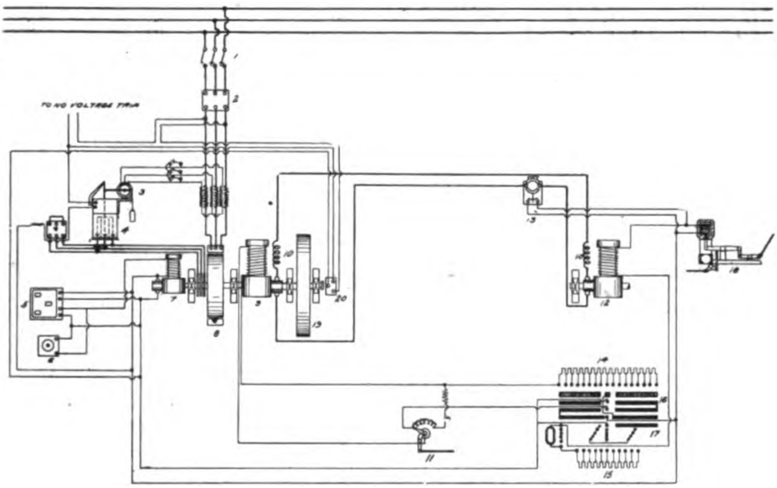


FIG. 15.—No. 1–2 line switches; No. 3–4 slip regulator; No. 5–6 Tirrill regulator and rheostat; No. 7–8–9–19 fly-wheel motor generator; No. 10 commutating pole and compensating field winding; No. 11 safety device; No. 12 hoist motor; No. 13 circuit breaker; No. 14–15–16–17 rheostat and controller of generator and hoist motor; No. 18 automatic brake solenoid; No. 20 speed limit device.

most common form, this regulator consists of a water rheostat connected in series with the induction motor armature. The resistance is varied by means of moveable electrodes suspended from an arm mounted on the shaft of an induction motor, which is connected in series, either directly or through series transformers, with the induction motor of the fly-wheel set. The regulator motor is so connected that its torque opposes the weight of the electrodes, which are partially counterbalanced to reduce the size of the regulator motor to a minimum, and permit of an adjustment

of the regulator for different values of line current. When the line current exceeds the value for which the regulator is adjusted, the torque of the motor overbalances the weight of the electrodes, lifting them and inserting resistance in the armature circuit of the induction motor. This causes it to slow down, and allows the fly-wheel to assist in driving the generator during the peak loads. The sensitiveness of this regulator varies with the line current, but within the range of ordinary operation the line current may readily be held within 5 per cent either side of the mean, provided the hoisting is done at a uniform rate and the regulator is adjusted for the average load. In actual practice the regulator must be set for the maximum condition, so that under ordinary conditions of hoisting, the current is limited rather than maintained constant.

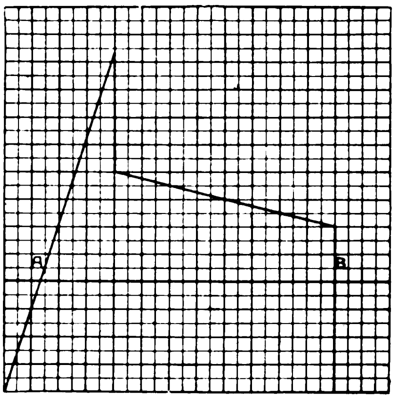


FIG. 16

The weight of the fly-wheel is determined from the hoist diagram by correcting it for the losses in the hoist motor and generator. Let Fig. 16 be such a diagram, and let *a*, *b* represent the average for the cycle. Then the energy represented by the portion of the diagram above the average line must be delivered by the fly-wheel during the peak load. The weight of the fly-wheel may be obtained from the equation

$$W = \frac{2\,g\,E}{V_0^2 - V_1^2}$$

where W = effective weight of wheel, V_0 = the velocity of the

wheel at a, Y_1 = the velocity of the wheel at b, and E = the energy in foot-pounds to be delivered by the wheel. It is the usual practice to make Y_0 approximately 300 ft. per second, in

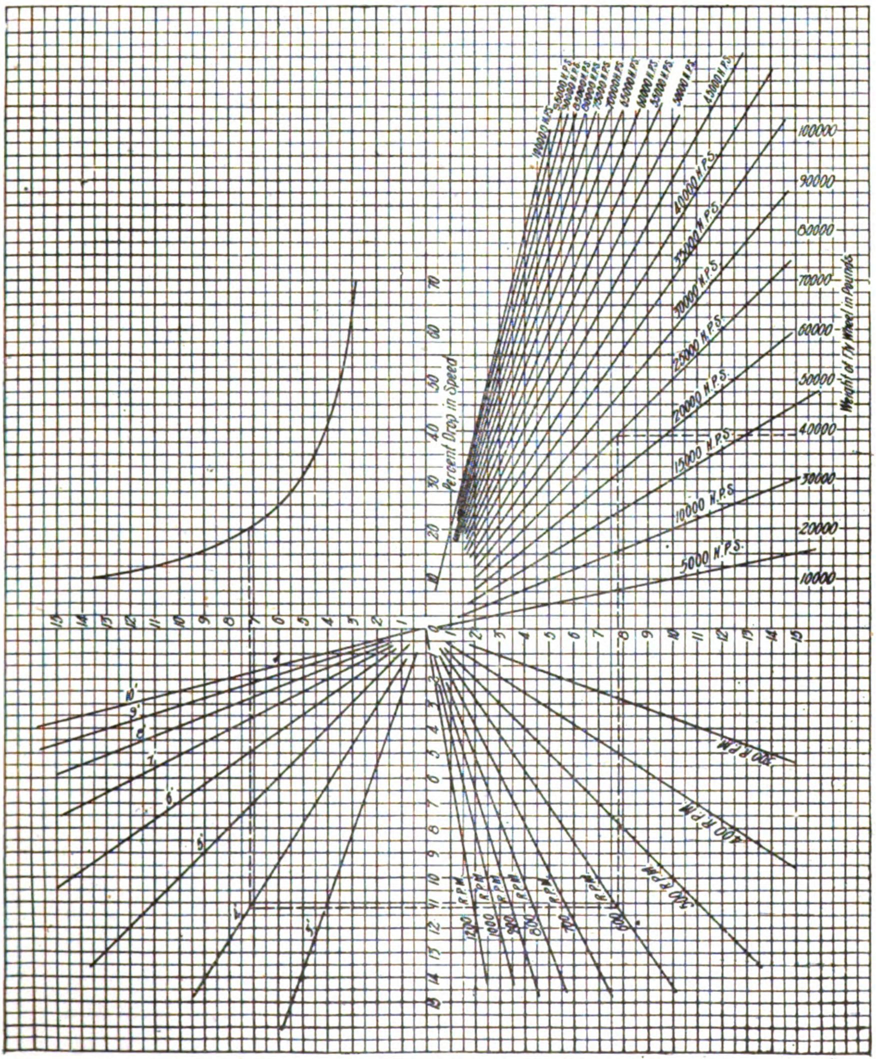


Fig. 17

which cases the actual weight of the wheel is approximately equal to 1.33 W.

A convenient method of obtaining the effective weight of a wheel is shown in Fig. 17. Having decided upon the radius of

gyration in feet, and the speed in revolutions per minute, the weight of a wheel required to deliver any number of horse power seconds from 0 to 100,000 with any change of speed from 10 per cent to 70 per cent may be obtained by the use of this diagram. To find the weight of a wheel, begin with the curve in the upper right hand corner of the diagram, and follow the line corresponding to the per cent change in speed until it intersects the curve, and then to the left until it interesects the line corresponding to the radius of gyration of the wheel, and so on as indicated by the dotted line, which assumes a wheel having a radius of gyration of 4 feet, running at 600 rev. per min. and delivering 25,000 horse-power seconds with a 20 per cent drop in speed. The effective weight of the wheel is approximately 39,000 lb. From the shape of the curve in the upper right hand corner, it follows that the weight of the wheel increases very rapidly for drops in speed less than 15 per cent, and that little is gained by increasing the drop beyond 35 per cent. On the other hand, the cost of the motor and generator decreases, and the efficiency of the induction motor increases, and therefore the power consumed per cycle decreases as the drop in speed decreases. The usual practice is to allow approximately 15 per cent drop in speed for balanced operation, but as the fly-wheel must take care of the unbalanced cycle without reducing the speed of the generator so low as seriously to affect its commutation, it is necessary to vary this value considerably in special cases.

The power and current curves for this system are shown in Figs. 18 and 19. The drop in the power curve of the balanced cycle during the period of rest, is due to fact that the regulator is set for the maximum condition, which in this case is hoisting unbalanced, this setting being above that required for the balanced cycle.

The fourth system is used when, for the purpose of meeting some peculiar condition, it is advisable to drive the hoist by an induction motor and at the same time eliminate the peaks from the station load. The adoption of this system is warranted when the hoist is located underground at such a distance from the surface that it becomes necessary to transmit power to it by alternating current, and when the shaft is not large enough to allow the fly-wheel of the motor generator set, to be taken underground.

Fig. 20 shows this system, which it will be noted is the first system, to which has been added a converter equalizer, consisting

of a rotary converter connected on the alternating-current side to the supply system, and on the direct-current side to a motor driving a large fly-wheel. The field of the direct-current motor is controlled by a regulator actuated by the line current. When the power taken by the hoist motor drops below the average, the field of the motor is automatically reduced, and the fly-wheel

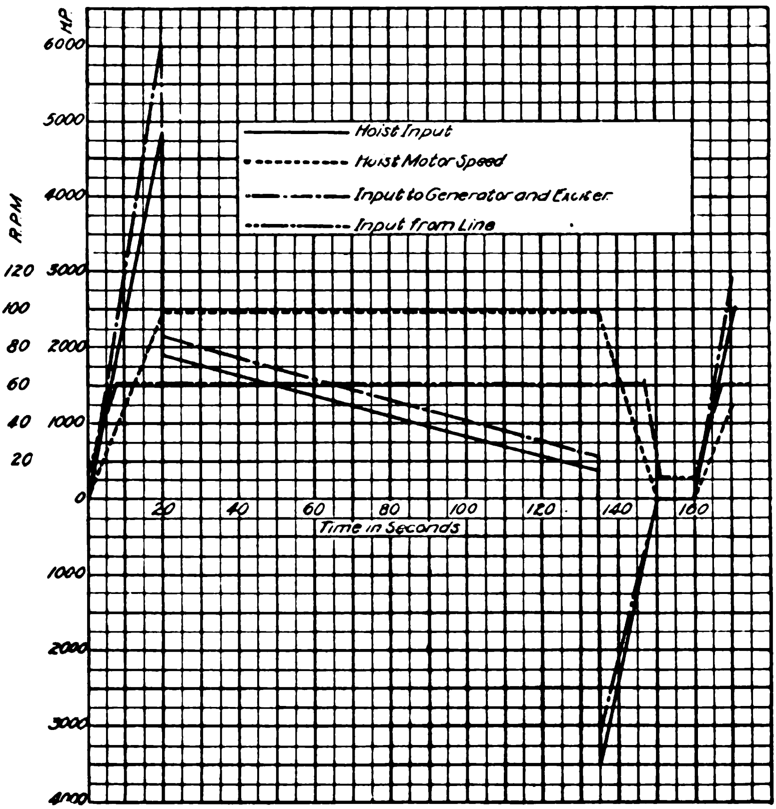
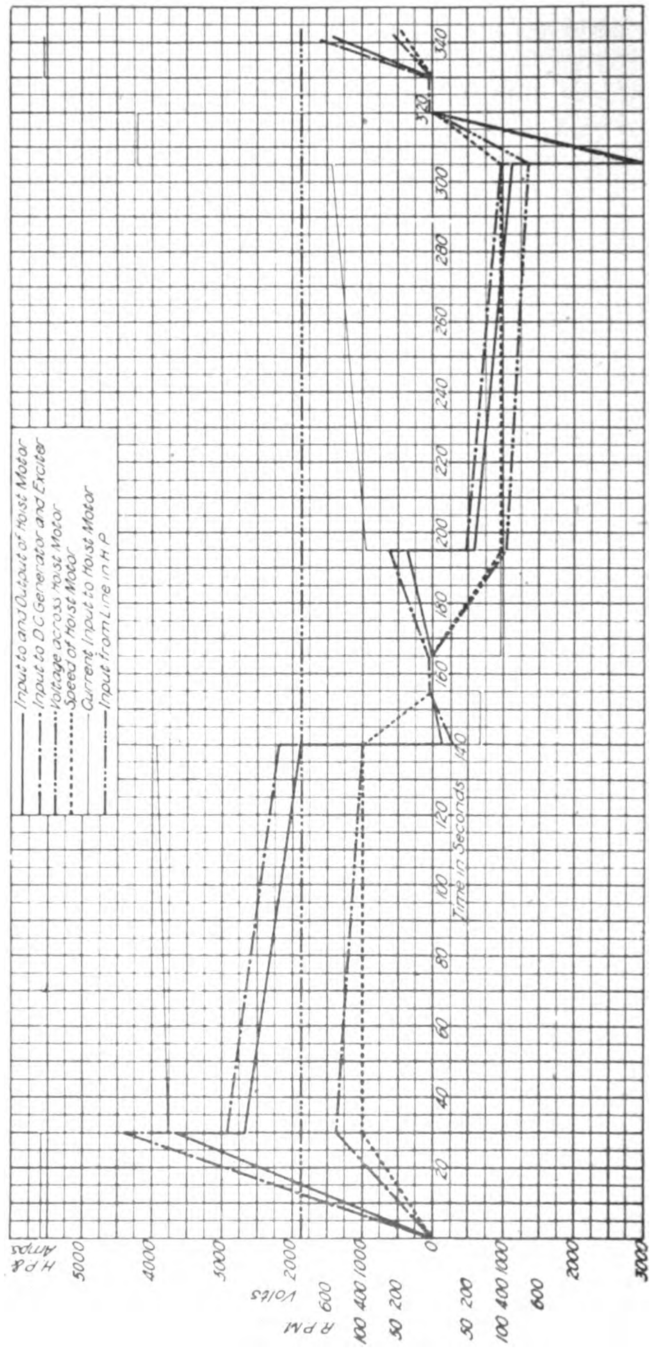


Fig. 18

is speeded up, the power being taken from the supply system. When the hoist-motor load exceeds the average, the operation is reversed, the fly-wheel slowing down and returning power to the system.

Fig. 11 gives the current and power curves which are those of he first system to which has been added the input curve with



Input to and Output of Hoist Motor
Input to D.C. Generator and Exciter
Voltage across Hoist Motor
Speed of Hoist Motor
Current Input to Hoist Motor
Input from Line in H.P.
Time in Seconds
H.P. & Amps
Volts
R.P.M.

FIG. 19

converter equalizer. The efficiency of this system is generally slightly lower, and the weight of the fly-wheel is slightly greater than for the direct-current motor and the fly-wheel motor-generator set. It has the advantage, however, over the third system, in that the operation of the hoist motor is not dependent on the operation of a converter equalizer. Consequently in the event of the failure of the latter, hoisting may be continued, providing, of course, that the capacity of the power system is sufficient to

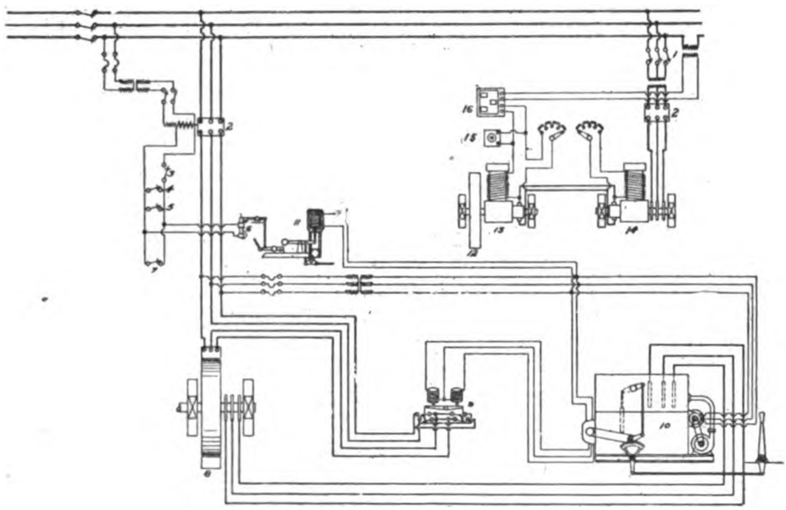


FIG. 20.—No. 1-2 line switches; No. 3–4–5–6–7 safety switches for preventing overwinding and stopping the hoist; No. 8 hoist motor; No. 9 reversing switch; No. 10 liquid controller; No 11 automatic brake; No. 12-13 fly-wheel dynamo; No. 14 rotary converter; No. 15–16 Tirril regulator and rheostat.

take the load, which would be the case if the equalizer were used simply to reduce the power bill.

Either the third or the fourth system may be used where the supply system is direct current, by substituting a direct-current motor for the induction motor of the fly-wheel motor-generator set in the third system, and omitting the synchronous converter of the fly-wheel converter system in the fourth.

Among other systems of electric hoisting which might be mentioned, is the Creplet system, in which a booster driving a heavy

fly-wheel is connected in series with the hoist motor and the supply system. The booster is wound for the same potential as the supply system, and the hoist motor for twice this potential. When the hoist is idle, the hoist motor armature is short-circuited, the booster is thus connected across the supply system and the speed of the fly-wheel is at its maximum. To accelerate the hoist, the short-circuit is opened, and the potential of the booster is gradually reduced to zero, reversed, and brought up to full potential in the opposite direction, the power stored in the fly-wheel during the idle period being returned.

It has been proposed, and at least two installations embodying the idea are now in process of construction, to substitute compressed air for steam. The present hoist engines would be used with slight modification of their valves to accommodate them to compressed air, the compressors for supplying the air to be driven by electric motors. It is impossible, however, to gather sufficient details regarding the system to predict the results which will be obtained.

A typical mine-hoist log is given in Table A, which is the condensed log for 24 hours, taken at a mine under actual conditions.

TABLE A
TIME IN MINUTES AND SECONDS

Interval	Hoisting ore	Hoisting men	Hoisting waste	Other hoisting	Shifting	Rest
7–8 A.M.	—	10–2	6–37	6–28	7–39	29–14
8–9	24–5	—	3–0	2–47	6–44	23–24
9–10	14–2	3–55	5–0	6–12	15–15	15–56
10–11	30–25	—	12–0	1–30	8–35	7–30
11–12 M	57–55	—	—	1–5	1–0	—
12–1 P.M.	3–35	1–0	17–5	2–55	4–29	30–56
1–2	51–10	1–50	—	1–45	4–0	1–15
2–3	20–10	—	—	2–40	12–5	25–5
3–4	44–0	—	—	0–51	5–25	9–44
4–5	—	7–38	—	1–25	0–38	50–19
5–6	—	—	—	—	0–35	59–25
6–7	—	13–8	—	1–23	0–27	45–2
7–8	21–27	—	16–42	1–54	2–1	17–56
8–9	51–7	1–8	—	4–57	1–59	0–49
9–10	54–17	—	—	1–30	1–30	2–43
10–11	48–22	1–42	—	—	2–53	7–03
11–12 M.M.	—	—	8–39	4–16	0–40	46–25
12–1 A.M.	34–51	1–52	—	—	0–30	22–47
1–2	53–14	—	—	2–49	—	3–57
2–3	50–25	—	—	1–10	—	8–25
3–4	—	7–50	—	25–43	1–0	25–27
4–5	—	—	—	55–47	0–34	3–39
5–6	—	—	—	5–14	—	54–46
6–7	—	—	—	3–09	—	56–51

Table B gives a condensed summary of this log, and also that of another mine under actual operating conditions.

TABLE B

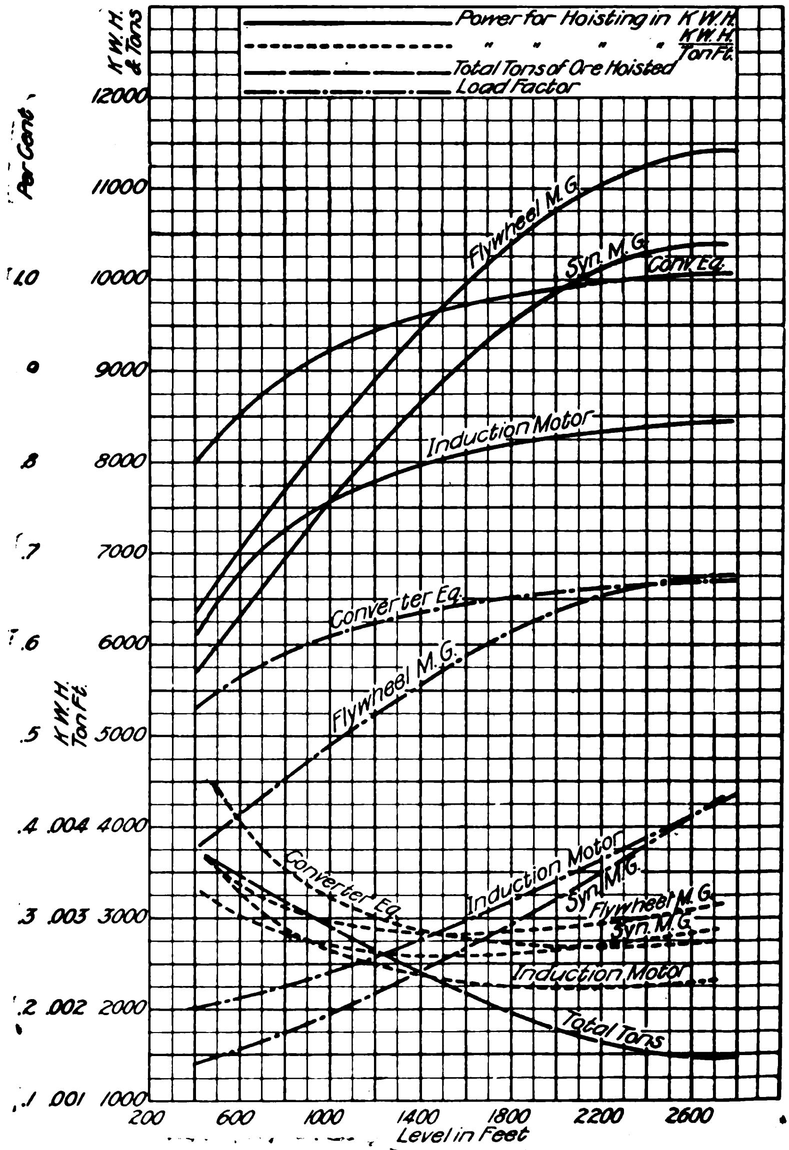
	Mine A			Mine B	
	Min.	Sec.	Per cent	Approx. min.	Approx. per cent
Hoisting ore and waste....	628	8	43.7	428	30
Other hoisting............	185	15	12.9	171	12
Shifting..................	77	59	5.4	120	8
Rest......................	548	38	38	721	50

The estimated distribution of power consumed for hoisting is given in Table C. Attention is called to the close agreement between the estimates for the power consumed in hoisting ore and waste, which, in view of the fact that the estimates were made entirely independent of each other, should add considerable weight to the figures. One estimate is based on figures obtained by indicating the hoisting engine, and the other forms the basis for the distribution of the costs of hoisting.

TABLE C

	Distribution of power in per cent of total	
	Mine A	Mine B
Hoisting ore and waste................	55	51
Other hoisting........................	28	23
Shifting..............................	17	26

The curves in Fig. 21 give the total tons hoisted, and the total kilowatt hours consumed (per day of 24 hours), the kilowatt hours consumed per ton (2000 lb.) foot, and the load factor for each of the four systems when hoisting 10,000 lb. per trip in balance from vertical depths, varying from 400 ft. to 2600 ft. by a reel hoist. Fig. 22 gives similar curves for hoisting 20,000 lb. of ore per trip in balance, from depths varying from 3000 ft. to 8000 ft., by a cylindrical drum hoist, the shaft making an



Power for Hoisting in K.W.H.
" " " " K.W.H. / Ton Ft.
Total Tons of Ore Hoisted
Load Factor
K.W.H. & Tons
Per Cent
K.W.H. / Ton Ft.
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.004
.003
.002
.001
200
600
1000
1400
1800
2200
2600
Level in Feet
Flywheel M.G.
Syn. M.G.
Conv. Eq.
Induction Motor
Converter Eq.
Flywheel M.G.
Converter Eq.
Induction Motor
Syn. M.G.
Flywheel M.G.
Syn. M.G.
Induction Motor
Total Tons

FIG. 21

angle of approximately 38 degrees with the horizontal, and the depths being measured on the incline.

Table D gives the power consumption for the various systems for hoisting 6000 lb. in balance from one level in a compound shaft, the hoist load diagram for which is given in Fig. 23. The shaft drops vertically 800 feet and then continues for 1320 feet on an incline of 38 degrees with the horizontal.

TABLE D

	Power for hoisting in kw-hr.	Power for hoisting in kw-hr, ton ft.		Total tons hoisted	Load factor
First system....	3900	0.00307*	0.00234†	786	25
Second "	3450	0.00272	0.00206	"	19.2
Third "	4019	0.00315	0.00240	"	62
Fourth "	4910	0.00386	0.00295	"	63.6

* Values are based on the total vertical lift 1613 feet.
† Values are based on the total distance lift 2120 feet.

The values given in these curves and table, include the power consumed in " other hoisting " and " shifting ", on the assumption that the power consumed in hoisting ore is 53 per cent of the total power. Also in the values for the synchronous motor-generator set (second system) no credit is allowed for the power returned during retardation.

These curves and table show clearly the effect of the shape of the hoist diagram on the power consumed by the various systems. At the upper levels the period of acceleration is a large part of the total cycle, and we find the power consumed by the induction-motor hoist to be greater than that for the hoist driven by the direct-current motor, power for which is supplied by a synchronous or induction-motor-generator set. In the case of the cylindrical drum hoist, for which the peak during acceleration is much greater than for the reel hoist, the power consumed by the induction motor is greater for all levels. Also a similar relation exists in the power curve when a converter equalizer or a fly-wheel motor generator set is used.

If a cylindrical drum is used instead of a reel, the curves of Fig. 21 for the direct-current hoist motors will remain practically the same, but those for the induction hoist motor will be raised,

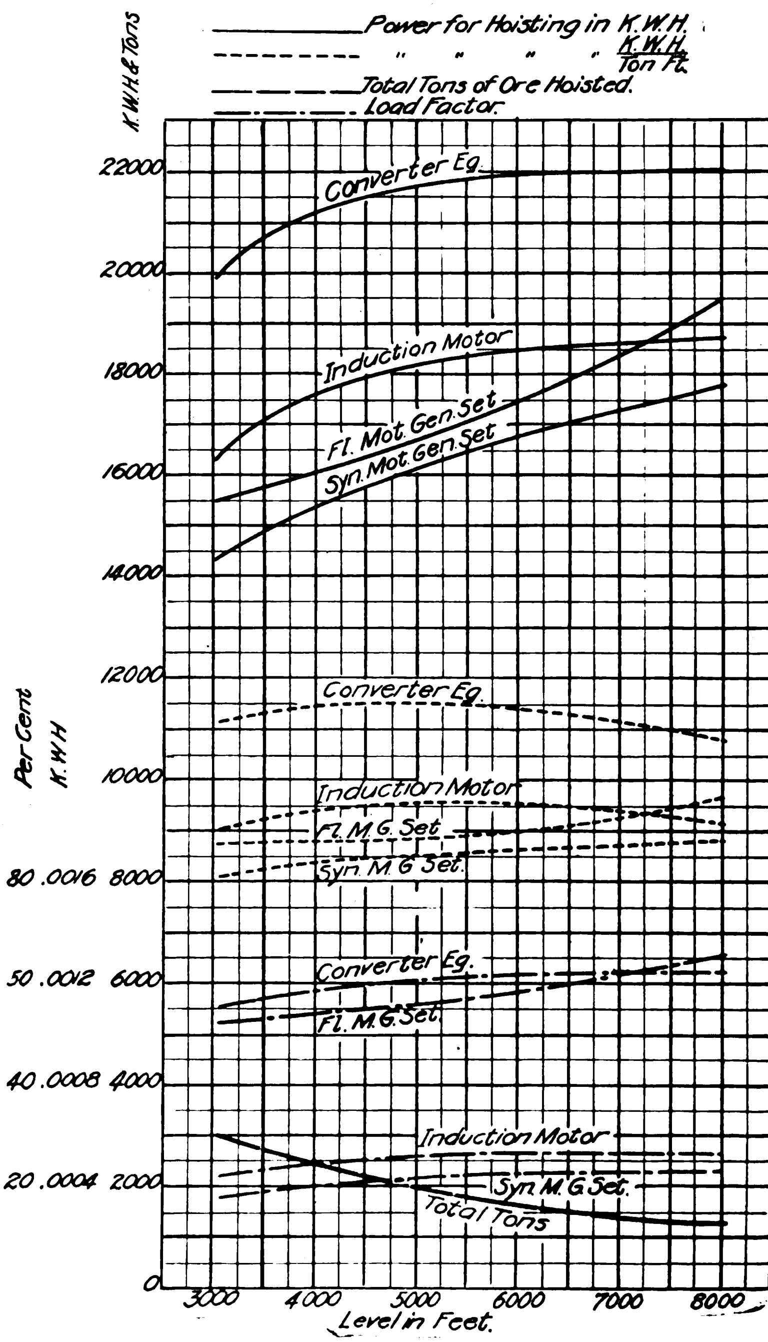

Power for Hoisting in K.W.H.
" " " " K.W.H. / Ton Ft.
Total Tons of Ore Hoisted.
Load Factor.
K.W.H.& Tons
Per Cent
K.W.H
22000
20000
18000
16000
14000
12000
10000
80 .0016 8000
50 .0012 6000
40 .0008 4000
20 .0004 2000
0
Converter Eq.
Induction Motor
Fl. Mot. Gen. Set
Syn. Mot. Gen. Set
Converter Eq.
Induction Motor
Fl. M. G. Set
Syn. M. G Set.
Converter Eq.
Fl. M. G. Set
Induction Motor
Syn. M. G. Set.
Total Tons
3000
4000
5000
6000
7000
8000
Level in Feet.

FIG. 22

crossing those of the synchronous motor generator set toward the end of the curve; and if a cylindro-conical drum is substituted for the cylindrical drum of the larger hoist, the induction-motor curves of Fig. 22 will approach those for the direct-current hoist motor.

The values for the different levels, shown by the curves, are based on the assumption that all the ore is taken from the corresponding level. Where ore is hoisted from several levels, the total power consumption per day may readily be obtained from the power consumption per ton foot, or by use of the curves of " Total Tons Hoisted " and " Power for Hoisting in Kw-hr."

While the curves given, cover specific cases only, the examples chosen are typical, and by interpolating between the power consumed per ton foot for the 8000 ft. and that for the 2500 ft. hoists, the power per ton foot may be obtained for hoisting from any depth. Due correction is to be made for the inclination of the 8000 ft. shaft by dividing the values given by 0.616 to obtain the equivalent values for a vertical shaft. From the total kilowatt hours consumed per day and the load factor, the cost of power for hoisting electrically can readily be obtained.

TABLE E

	Coal burned tons per day	Ore hoisted tons per day	Tons ore / tons coal
Hoisting from 2000 ft. level small hoist:			
Steam hoist	47.0	1780	40
Elec. hoist First system	13	"	137
Second "	15	"	119
Third "	16	"	110
Fourth "	15	"	119
Hoisting from 6000 ft. level large hoist:			
Steam hoist	65.5	1580	24
Elec. hoist First system	23	"	69
Second "	24	"	66
Third "	25	"	63
Fourth "	27	"	59

A comparison between steam and electric hoisting, is given in Table E in which the coal and rock ratio for each are given for the 2000 ft. and the 6000 ft. levels respectively. In deter-

mining these values, it is assumed that the steam hoisting engines are non-condensing, that the steam consumptions are 65 lb. and 55 lb. per indicated horse-power hour respectively for the large and small hoists, and that power for the electric hoists is supplied from a modern steam turbine station using units of 1000 kw. each, or larger for the smaller hoist and 2500 kw. or larger for the larger hoist.

In determining these ratios, 10 per cent has been added to the total kilowatt-hours per day as given in the curves, to cover the losses in transmission.

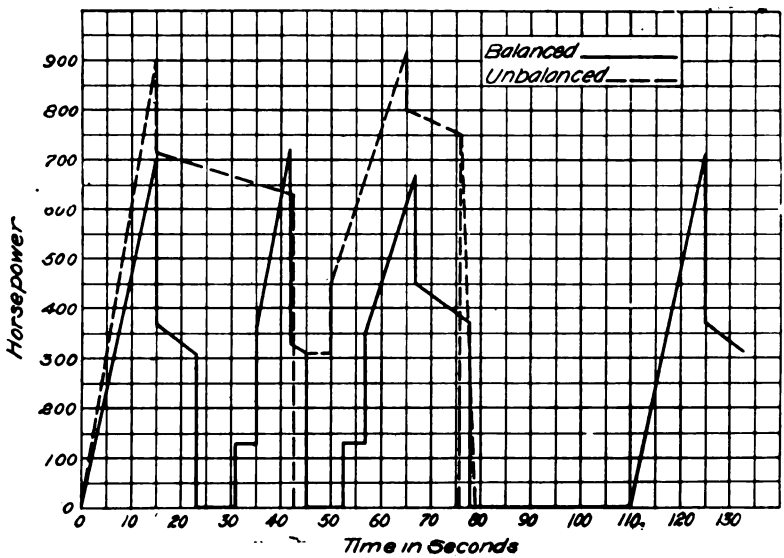


Fig. 23

In addition to the saving in fuel which may be realized by the use of electric hoists, there is a very material reduction in the labor, the cost of which is chargeable against the hoist. This may amount to the wages of one or two men in the boiler house if power is developed by the mining company, or of the whole boiler-house force if power is purchased, and frequently the wages of one man in the hoist house.

So many factors which vary between wide limits for different localities enter into the comparative costs of hoisting electrically and by steam, that each individual case must be treated by itself,

but the following comparison will serve as an indication of the general result of a more detailed investigation.

Take for example the reel hoist, the power curves for which are shown in Fig. 21, and assume that the average condition of hoisting is that represented by hoisting from the 2000 ft. level; that good steaming coal can be purchased for $3.50 per ton; that power can be purchased for the equivalent of 1.1c. per kw-hr., on a 50 per cent load factor, and, if steam driven, that the engine will be non-condensing.

In order to obtain a load factor of 50 per cent, it will be necessary to install either the third or fourth system of electric hoisting, and, to be conservative, let it be assumed that the third is chosen.

Total cost of power per year for electric hoist at 1.1c. per kw. hr	$35,300
Fixed charges on the excess cost of the electric over the steam hoist (approx. $25,000)	2,500
	$37,800
14100 tons coal at $3.50 per ton	$49,350
Boiler-house force (3 men at $3.25 per day)	2,925
One oiler	900
	$53,175
	37,800
Approximate annual saving with electric hoist	$15,375

As this saving of $15,375 is the result of an additional expenditure of $25,000 for the electric hoist, it is proper for a new installation to base the rate of interest equivalent to this saving on this additional first cost, from which it follows that the interest realized on this investment is 61.5 per cent. If, on the other hand, it is a question of replacing an existing steam hoist, the interest should be based on the total cost of the electric installation, in which case the very substantial rate of 30 per cent will be realized.

The hoist, above all other parts of the mine equipment, must be kept in commission at all times, and this fact must be borne in mind in installing an electric hoist. The transmission lines must be carried on substantial poles over a well-cleared right-of-way, duplicate lines being installed where possible and the

lines being adequately protected against disturbances from lightning. If these precautions are properly taken, the electric can be made as thoroughly reliable as the steam-driven hoist.

Summing up, the advantages of the electric hoist are: first, greater economy, resulting from the centralization of the development of power in a large central electric station, favorably located for the economical development of power and from a reduction in the operating force, from the increased life of the rope and the greater life of the brakes; second, greater safety in operation; third, especially, adaptation for underground installations, and fourth, the fact that it permits of the utilization of water power which is frequently available in mining districts.

NOTE

The following paper is to be read at the 246th meeting of the American Institute of Electrical Engineers in **Charlotte, N. C., March 30—April 1, 1910.** This paper is to be presented under the auspices of the Industrial Power Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **D. B. Rushmore, General Electric Co., Schenectady, N. Y.,** so that they will be received not later than March 28, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

ELECTRIC DRIVE IN TEXTILE MILLS

BY ALBERT MILMOW

It is the purpose of this paper to deal especially with the employment of electric power, derived from hydroelectric systems of distribution, for the operation of textile mills. It is impossible in a paper of this kind to go very fully into detail, and no attempt will be made to discuss the forms of drives, kind of motors or, in fact, any other technical details, since any one of the more important ones would require a special paper to do it justice.

This paper aims to treat the subject from a broad, general viewpoint, with particular reference to its commercial aspects, and especially in comparison with the old forms of steam drive.

The general branches of the subject which will be taken up are first cost, cost of operation, production as affected by balancing and speed, and general remarks.

First Cost

The references which follow will be to new mills especially equipped for electric drive, insofar as first cost is considered, and not to mills already equipped with steam power. The figures are based on a plant of 25,000 spindles on moderately fine work, which requires a power equipment of about 1000 h.p. The figures which follow are for everything included in a mill that is chargeable to the power plant:

Electric Drive

Group drive throughout, all 2300-volt motors. Power delivered at 2300 volts.

Transformer house and switchboard room	$1,000.00
Belting	1,300.00
Motor support	400.00

Shafting	$8,000.00
Boilers	1,200.00
Boiler setting	350.00
Boiler room	1,650.00
Reservoir	1,800.00
Piping	900.00
Motors	10,560.00
Transformers for low voltage motors, 2 to 5 kw	126.00
Transformers for lighting, 1 to 50 kw	383.00
Switches for motors	300.00
Switchboard	1,500.00
Wiring and installation, including lighting	4,000.00
Freight on electrical apparatus	428.00
	$33,897.00

MECHANICAL DRIVE

Boiler room Engine room Chimney	$16,000.00
Engine, 24-rope wheel, compound	17,500.00
Engine foundation	2,000.00
Boilers	6,000.00
Boiler setting	1,800.00
Smoke breeching	770.00
Condenser, pumps and heaters	2,520.00
Reservoir and crib	6,500.00
Steam power piping	6,000.00
Ropeway and extra sprinklers	2,000.00
Shafting and structural steel work	12,053.00
Rope	600.00
Belting, main drive and counters	1,300.00
Lighting generator, belted, and switchboard	1,000.00
Marine engine generator, 10 kw., and switchboard	1,000.00
Lighting wiring, 2-wire system	2,000.00
Total	$79,043.00

From the table it will be seen that the total cost of the power plant for steam drive would be $79 per h.p., while the cost for a similar electric equipment is $33.90 per h.p., or a saving of $45.10 per h.p. of plant capacity where the electric drive is used.

It is to be noted that all costs are included in these estimates, though it is quite usual for advocates of steam drive to take for its first cost only the costs of engines, boilers, piping, etc., neglecting such important items as building chimneys, belt-ways, condenser reservoirs and other items which are essential to steam drive, but which are not required where a mill is electrically driven. This difference in cost should enter into the cost of

power, taking the interest and depreciation at 12 per cent, the lowest possible figure. However, it is obvious that if this same amount of money were expended in producing textile machinery the earnings would certainly exceed the 6 per cent included in this figure as an interest charge.

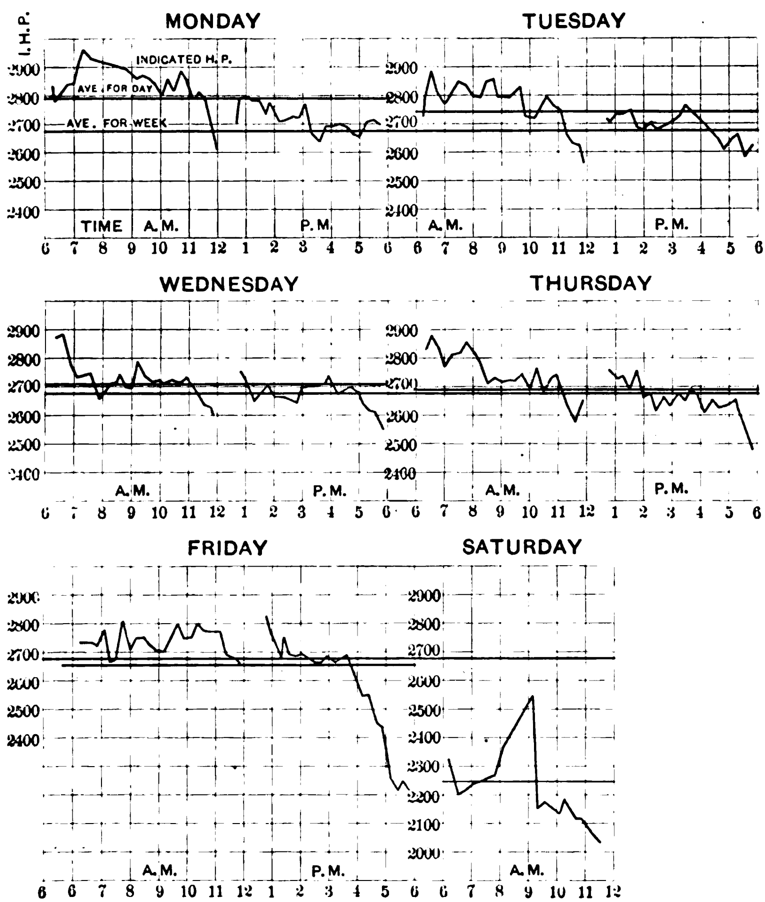


Fig. 1

Cost of Operation

The cost of steam power in a textile mill is very difficult to determine. Fig. 1 shows a series of engine indications made for a period of one week, at ten minute intervals. It will be noted that a very wide variation of power is shown and only a very

thorough and detailed set of indications, as shown here, will give a fair average of the amount of power.

It is customary with advocates of steam drive to make certain large deductions in a purely arbitrary manner from the total cost, for the values of steam used in processes of manufacture other than for power, such as dye-house operation, heating and slashing, and then to divide the remainder by a factor obtained by taking one or more engine indications.

It will be seen from Fig. 1 that it is obviously erroneous to take any value for the total horse power of a mill other than an average taken approximately as shown; even this, to obtain perfectly accurate results, should extend over a long period, embracing all the seasons of the year, as there are many variable quantities involved, such as the temperature of the mill, which varies with the seasons, the humidity of the air, and even the nature of the cotton staple.

These factors cause an extreme variation of power during, say, a year's period of as much as 20 per cent, and this variation is very noticeable in a day's or a week's run, as will be seen by the variations of power as shown in Fig. 1 on that part of the curve corresponding to Monday.

On account of using the same boilers for power and for other purposes it is difficult to obtain accurate figures on the cost of dye-house, heating, and slasher operation in a steam-driven mill. Where boilers are used for making tests it is usual to use a large power boiler, which runs in an underloaded condition and hence inefficiently, and the steam is often carried in long systems of piping before it is utilized. In electrically driven mills it has been possible to segregate these costs. The cost of heating a 10,000 spindle mill is, for the climate of the Piedmont region, about $250 per year, and as this size mill will use about 500 h.p., the cost of heating may be taken to be 50 cents per h.p. per year. This figure is for a boiler of just sufficient capacity for the work. Similarly, the cost of slashing is found to be $1.40 per h.p per year, or a total of $1.90 per h.p. per year for heating and slashing. Of course, this figure varies with the class of work, but it applies to work using an average of about No. 30 yarn. The figure commonly taken in estimating steam horse power cost is about $4.00 per h.p. per year, which is entirely too high. For these reasons it is very difficult to determine any accurate cost of the steam power on the horse power-year basis.

In dealing with about seventy mills electrically driven, many

of which have been converted from steam to electric drive, it is found that no two present identical conditions, and even when a mill is changed to electric drive, the opportunity of improving speeds, etc., is usually taken advantage of, and the mill is generally reorganized to an extent that precludes the possibility of a direct comparison.

It has been found, however, that where the machinery in a converted mill has been kept intact and the speed kept constant, and where accurate records of engine indications prior to the change have been kept (which is rarely done) a saving in the power required is effected, though most mills when making this change take the opportunity afforded of improving production in one or more ways and thus increase the power required. The manner of operating a mill is also important in determining the amount of power required. Some mill men force production to the highest point, while others are content to run at moderate speeds and production.

The varying cost of fuel, the quantity and varying temperature of condenser water, and the difficulty of obtaining accurate data make it impossible to arrive at any accurate conclusion regarding an average cost of steam-generated power in textile mills.

In electrically-driven mills the absolute horse power-hours and the indicated power can be determined at any time. An opportunity is given to check wastes and correct them, and a considerable amount of non-productive power is saved by the elimination of useless shafting.

Assuming the price of electricity to be $25 per h.p. per year for 11 hours per day, 306 days per year, and assuming a saving at equal production of 15 per cent in power, which I consider conservative, the cost at which steam power must be generated to equal the price of electric power will be $21.25. From this must be deducted the fixed charges on the difference in first cost, which we may take at 12 per cent on $45.10, or $5.41 per h.p. per year, leaving $15.84, plus $1.90 which will be required for the heating and slashing operations of the mill, or a total of $17.74 as the figure at which steam power must be generated to be equal in cost to electric power at $25 per h.p.; and in this figure there must be included the cost of all oil, waste, labor, fuel, ash removal, coal handling, superintendence and, most important of all, the item of repairs, which is frequently omitted entirely in making estimates of steam power cost. If it were

possible to attain this figure with a steam drive, a power only very inferior to electric drive would have then been obtained.

Production

Hydroelectric power offers many advantages in operation, due to the readiness with which parts of a mill may be run so that the maximum possible output may be obtained. By reference to Fig. 1 it will be noted that a wide variation of power is shown, due, among other things, to the fact that it is unnecessary to run all of the departments all of the time.

In a mill which has perfect balance, each piece of machinery used in each process will deliver to the next succeeding department just the right amount of material to keep both sets of machinery operating at full output all the time, and so on until the completed article of manufacture is produced. This is a condition difficult to realize, as in actual service it is found that market conditions in nearly every case make change of product necessary, and in a mill which can be designed for only a limited range of work, any variation from this affects all the preparatory departments by giving them more work for coarser product or less for finer product.

In mills which are used exclusively for spinning, and which do no weaving, a part of the product is in the form of twisted yarns and part of it in single yarns; hence the twister department, which uses a great deal of power, is often called upon to its full extent and again is often entirely idle.

In equipping a mill for electric drive it is usual and proper to provide one or more motors for each process of the work so that in case the demand on that department is increased, it is possible to work over time on that particular department, where, on account of the inefficiency of the engine at light loads and often because of the very small part of its capacity that is required, it would be impossible to run with a steam drive; or if some department, such as the twisters, is not needed at all, the motor provided for it can be shut down entirely, saving all expense of its operation without affecting the operation of any other department or in any way affecting its speed.

These points are actually taken advantage of and practiced to a very great extent. In mills using automatic looms they are frequently left in operation at the noon hour, when they will run until some threads break, when the loom automatically stops itself and remains stopped until the weaver returns. Many of

them continue in operation without interruption. In some cases looms are left in operation after shutting down time until the loom stops itself, which often does not occur until all the filling yarn is exhausted. These hours in the aggregate sum up a very respectable total in the course of the year.

The textile industry in the south is at a growing stage and few if any mills are left complete as first installed, especially among the larger mills. It is almost the usual thing to see a mill with one of its ends boarded up instead of closed with brick, thus proclaiming to the world the intention of its owners to extend it as soon as they can. In the days before electric power was available this necessitated a steam plant entirely too large for the first installation, so a plan was resorted to of installing one-half of an engine and operating this as a simple engine, with the ultimate intention of adding a cylinder for compounding when the mill should be increased. This arrangement necessitated the investment of a great deal of money in a steam plant to begin with, which to-day can be put into the manufacture of cotton goods, and resulted in very high costs for power when using only a simple engine. These conditions have too often proved a handicap which has prevented the mill men from realizing their hopes as soon as they might have done. With electric drive the system is perfectly flexible. Only the investment for the work actually installed is demanded at the outset, and the full output and efficiency are secured from the beginning.

An interesting application illustrating the flexibility of electric drive has recently been made and is being quite generally followed. In this case a mill was built with a capital of $100,000 and with an equipment of 5000 spindles for the production of yarns. It was the intention to operate this mill day and night and the promotion of the mill was based on this idea. It was found, however, that for the spinning frames, which require women and girls to operate them, sufficiently satisfactory labor could not be obtained to operate during the night run, so that the management found itself in a position of being able to offer to its stockholders a production based only on the actual money employed, or $100,000. Through their own initiative they then took advantage of the opportunity offered by electric drive and added to their equipment an amount of spinning machinery equal to that already installed. This operated with the rest of the equipment during the day time, and all preparatory machinery, for which only men are employed, is operated day and

night, thus giving material to the double number of spinning frames during the day. This resulted in a production equal to that of a mill of 10,000 spindles costing $200,000, while the total cost of the mill was only $120,000. The addition of the extra spinning machinery cost $20,000, and the original cost of the mill was $100,000. This arrangement has, simply by the proper use of electric power, saved the mill an additional burden of investment of $80,000, the interest and also the depreciation on which would more than eliminate the entire power bill.

The old idea of building a mill amounted essentially to first building a steam plant and then building the mill to conform to it, as its shape and the arrangement of the machinery had to conform to the most convenient ways of running shafting. In an electrically driven mill the matter of power is secondary. The machinery is placed in the most convenient way for operation as a textile plant and the motors are installed afterwards.

It has been found that in practically every mill that has been converted from mechanical to electric drive, an increase in production has been obtained. This is almost always the case and it is not usually taken account of by investigators of power costs. Among the uninformed there is a quite general opinion that the converted mill takes to operate it electrically as much as or more power than it previously did with steam. On account of the increased production with the electric drive this is true in a great many cases; but in many other cases it is uncertain, as no accurate records of steam indications have been taken or kept. The explanation of this increase in power is simply that the production has been increased. At the time the motors are installed the speeds of the mill are readjusted and nearly always increased, the power is applied more directly to the work with less chance of slippage of belts and, above all, the speed with motor drive is much more constant.

Figs. 2 to 51 show a series of curves taken with a delicate recording tachometer. The longitudinal lines each represent 1 per cent of instantaneous variation, and approximately one-half inch in length of the diagram shows an interval of time of one second. All of these charts shown were taken in actual service, excepting Fig. 6, which was taken to prove the accuracy of the instrument with the best known constant speed drive—a direct-current shunt motor supplied with current from storage batteries.

Fig. 2 shows a chart from a 3000-h.p. cross-compound engine, taken directly from the main driving shaft.

Fig. 3 shows one from a 1000-h.p. cross-compound engine.

Figs. 4 and 5 are charts taken directly from the shafts of an 85-h.p. and a 125-h.p. motor, respectively.

Fig. 6 is taken from a known constant speed.

Figs. 7 and 8 are from water turbines in operation and under load.

Figs. 9 to 15 inclusive show speeds of a shaft directly driven from one large engine through rope drives, with the exception of Figs. 10 and 15 in which the shafts were driven from a second belt. Fig. 10 is the record of a shaft driven by a belt from the shaft recorded in Fig. 9, and Fig. 15 a shaft belt-driven from that of Fig. 14.

Figs. 16 to 20 show the same shafts driven by motors after the mill has been converted. Figs. 9 and 16, 10 and 17, 11 and 18, 12 and 19, 14 and 20, 15 and 21 represent steam and electric drives, respectively.

It will be seen from these records that a very material improvement in initial speed and transmitted speed has taken place. This mill was selected, among many others, as being representative of a large well equipped mill, and the steam drive is much worse in many of the mills charted.

Figs. 22 and 23 are of particular interest as showing the torsional spring in the shaft. This represents a line of shafting about 300 feet long such as is commonly found in weave rooms. Fig. 22 was taken at the driving end and Fig. 23 at the extreme other end, showing that where the original speed was excellent it was badly perturbed before reaching the end of the shaft.

Figs. 24 to 32 show speeds in a steam driven weave room. Fig. 27 is taken with the engine drive and the others are counter-belted to the shaft in Fig. 23 on one side, and to that in Fig. 32 on the other. It will be noted that the original speed, which was good, has been increasingly perturbed by belting, so that the greatest variation in every case is shown on the last shaft. Figs. 33 to 41 show speed records of the same shafts driven by two large motors. It will be noted that a considerable general improvement has taken place.

Figs. 42 to 44 show very badly perturbed speeds. These represent the three main line shafts on which the entire machinery of a large mill depends. This speed variation is caused by bad belting and excessive end play in the shafts, causing crowning and slackening of the belts alternately.

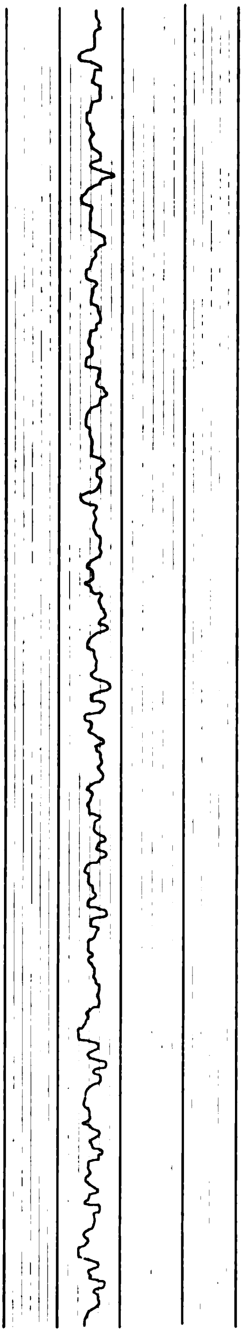


FIG. 2

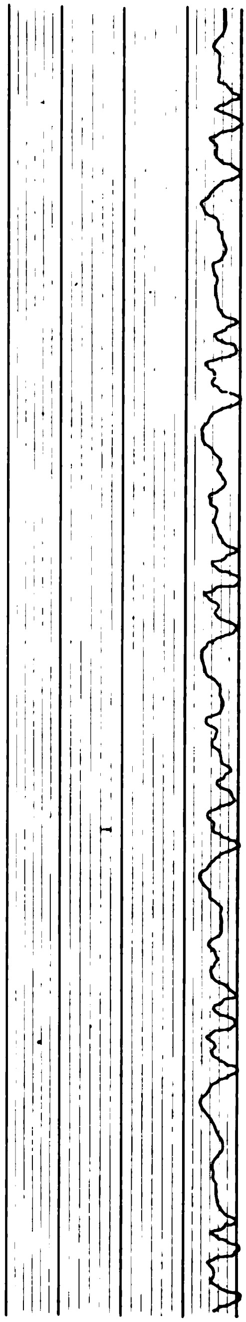


FIG. 3

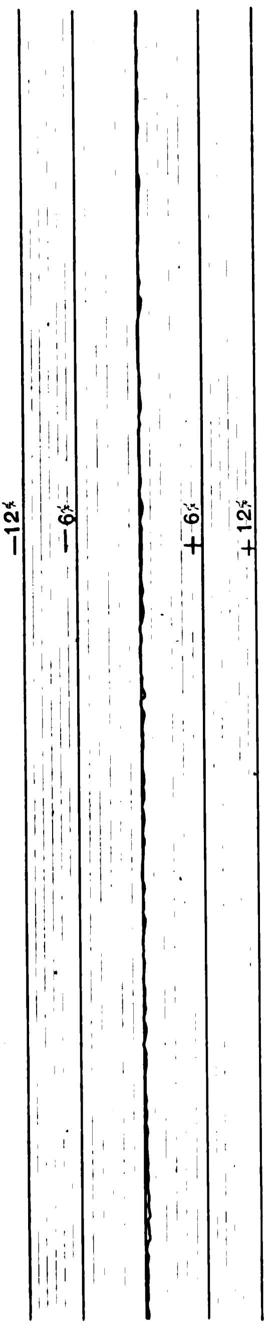


FIG. 4

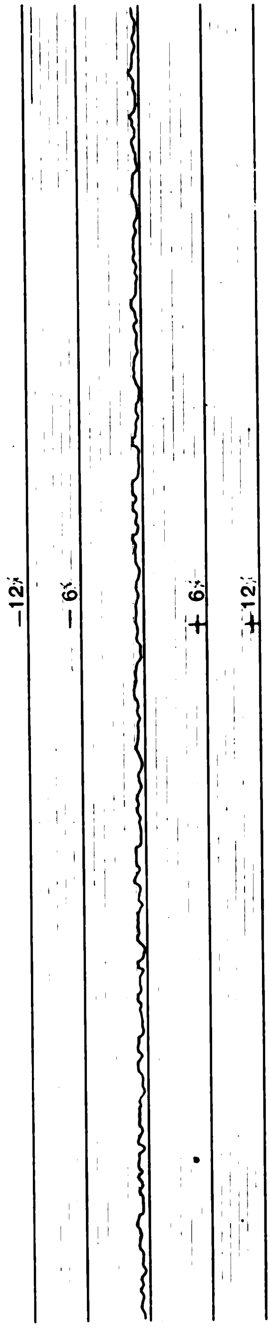


FIG. 5

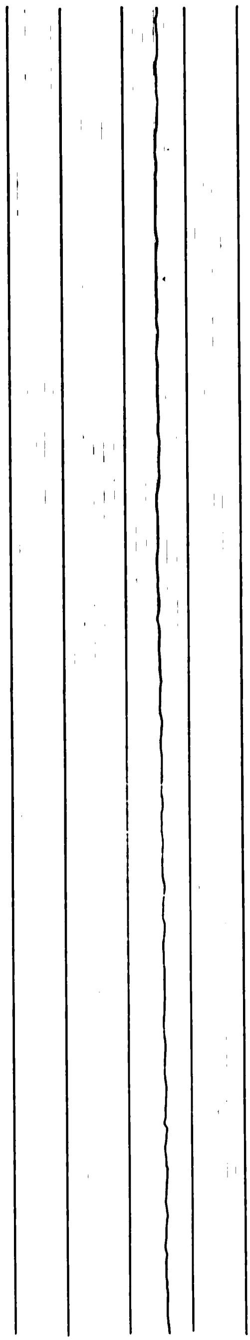


Fig. 6

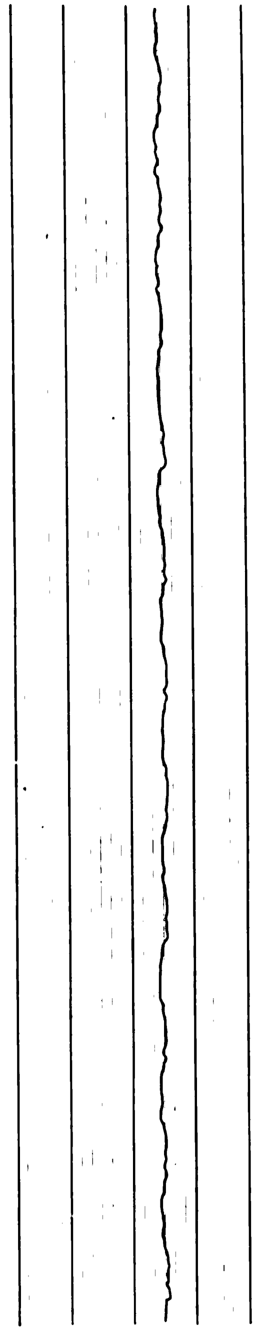


Fig. 7

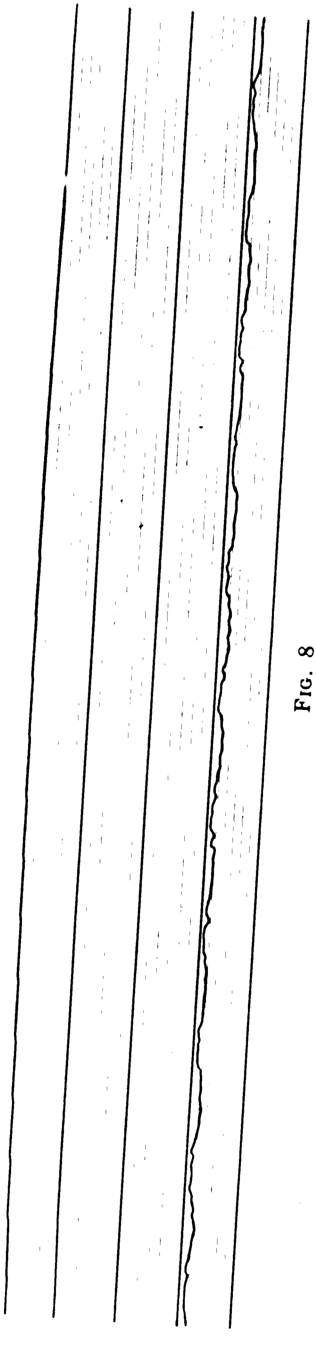


Fig. 8

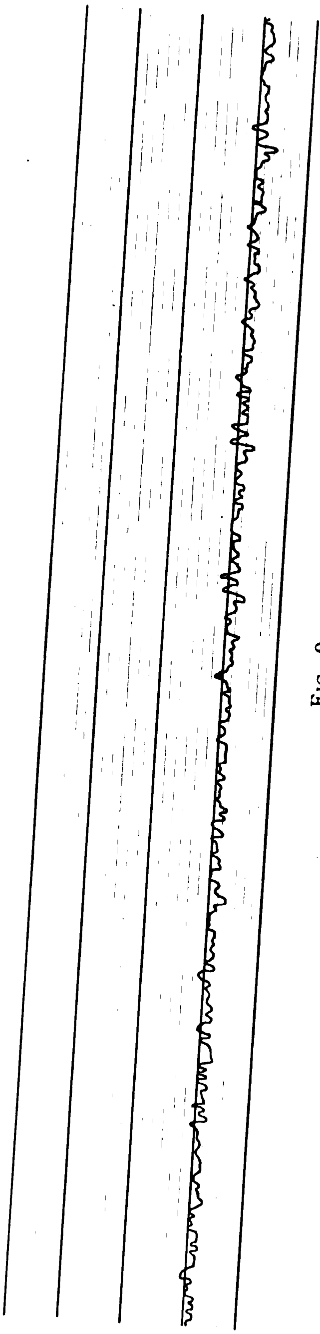


Fig. 9

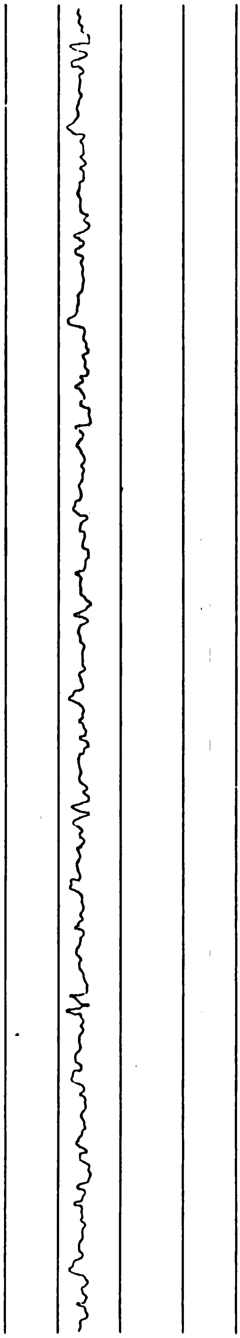


Fig. 10

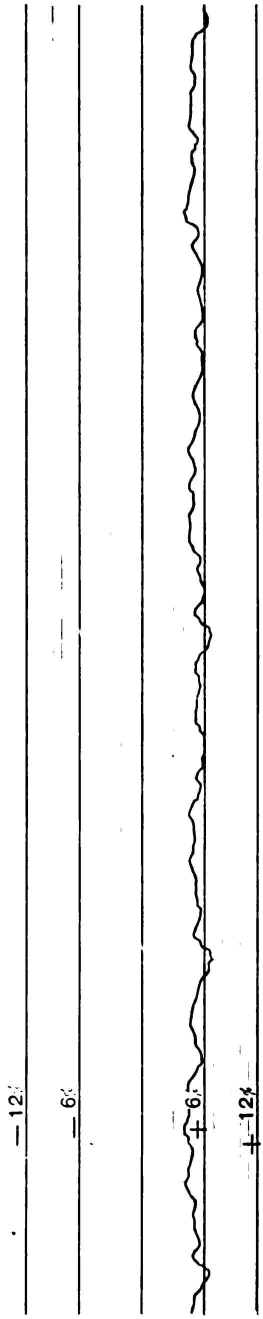


Fig. 11

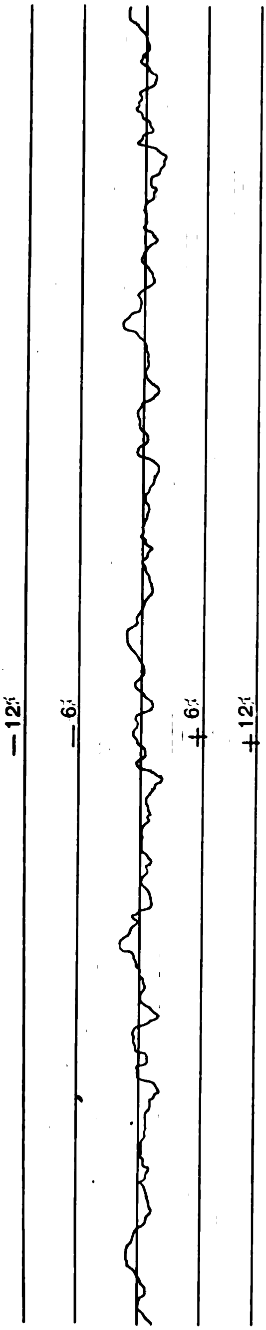


FIG. 12

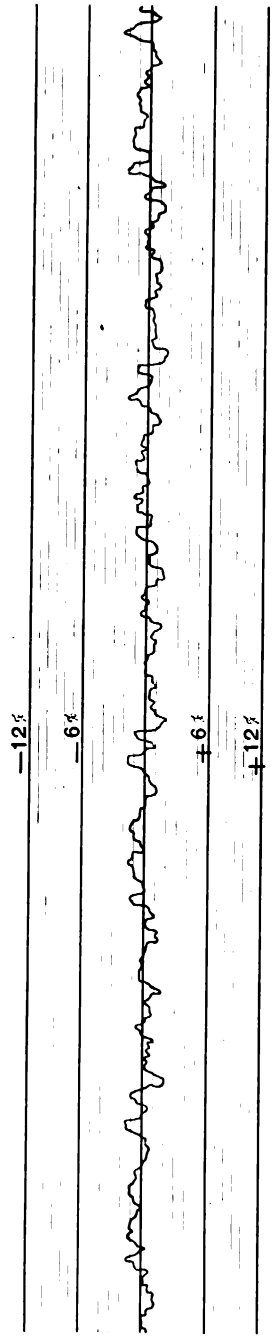


FIG. 13

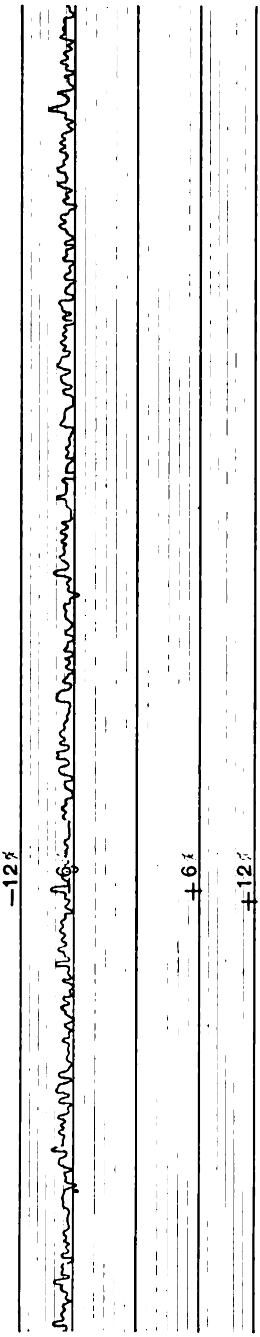


FIG. 14

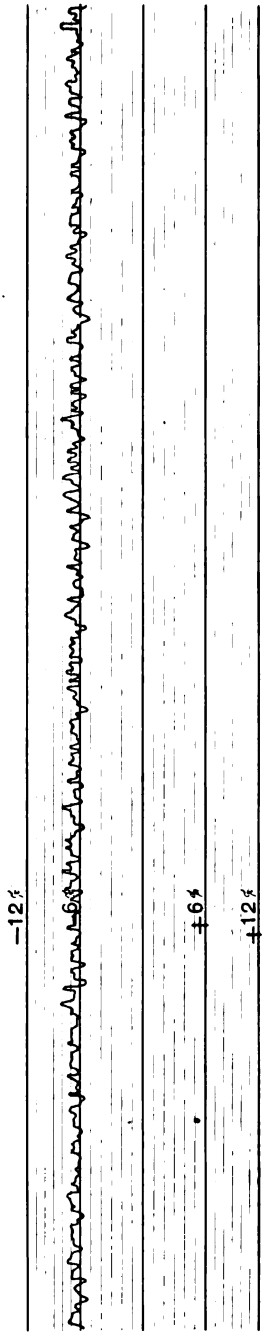


FIG. 15

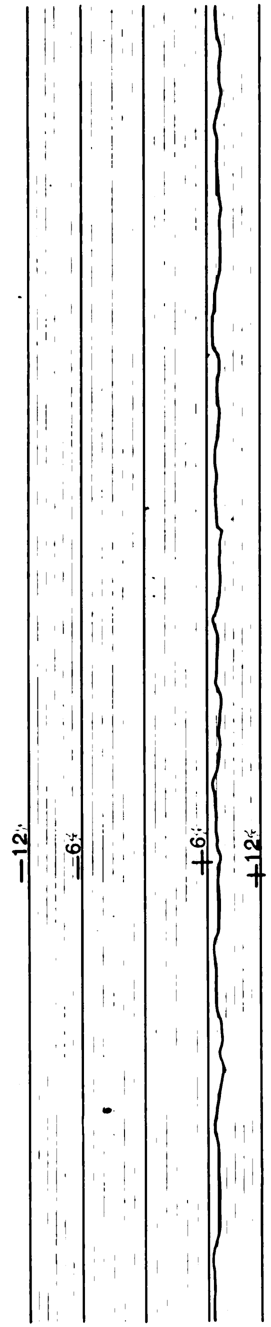


FIG. 16

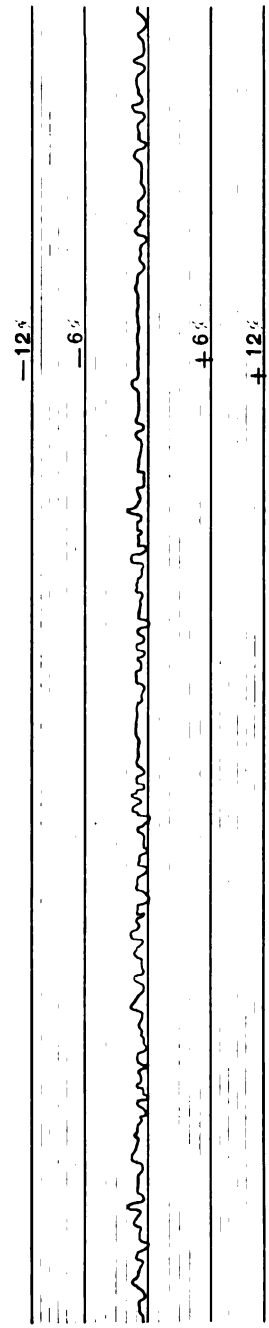


FIG. 17

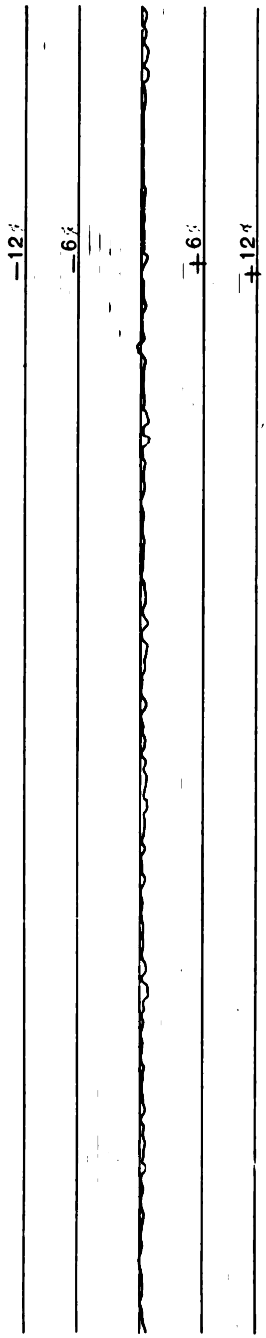


Fig. 18

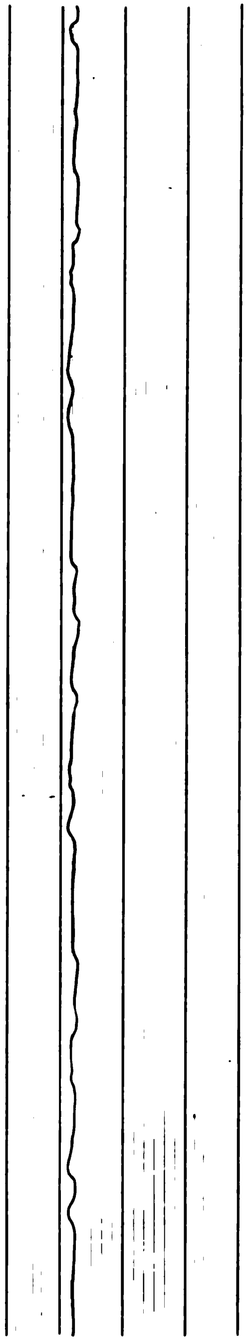


Fig. 19

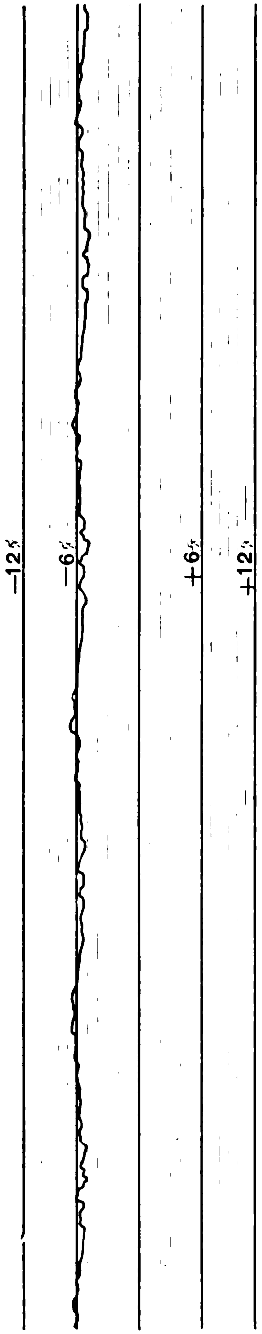


Fig. 20

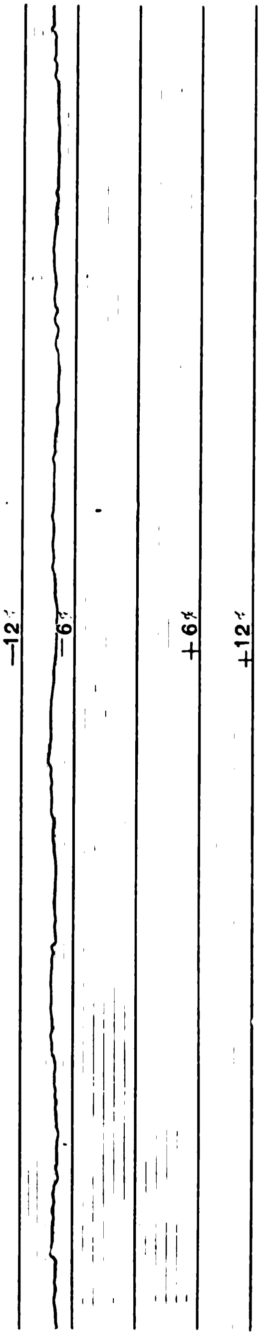


Fig. 21

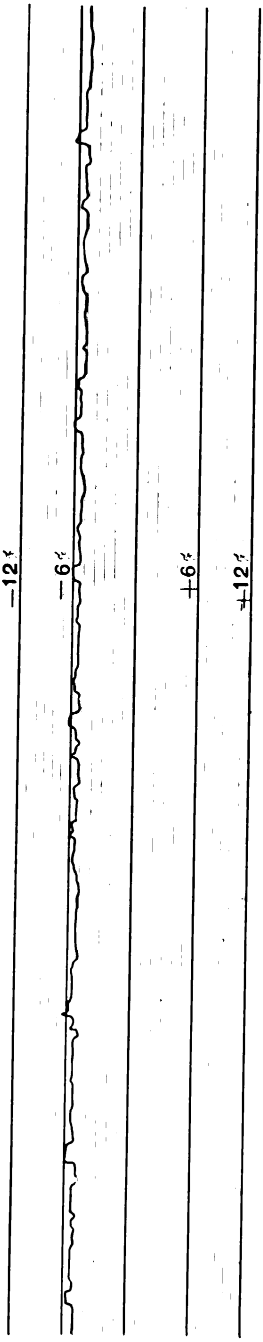


Fig. 22

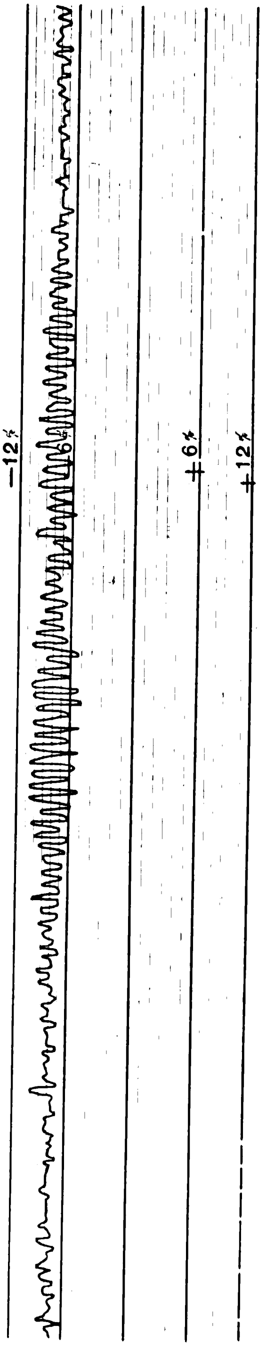


Fig. 23

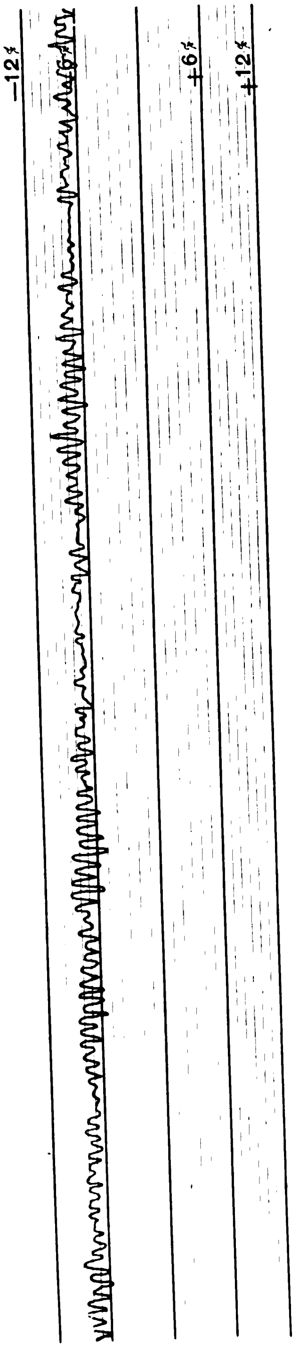


FIG. 24

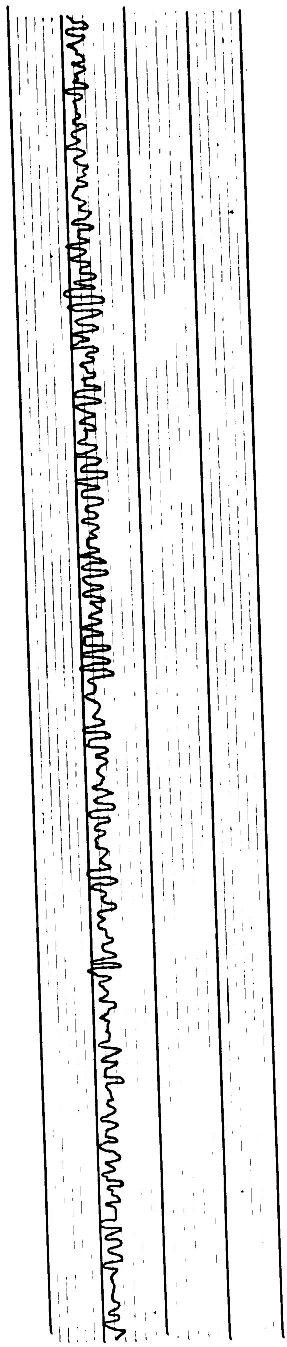


FIG. 25

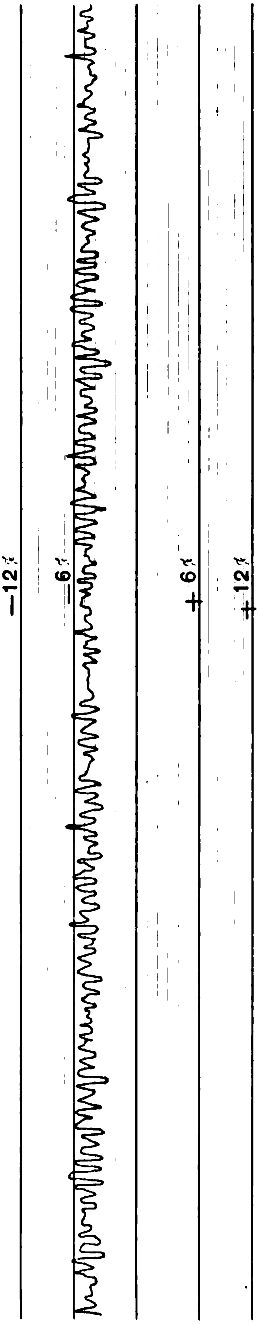


Fig. 26

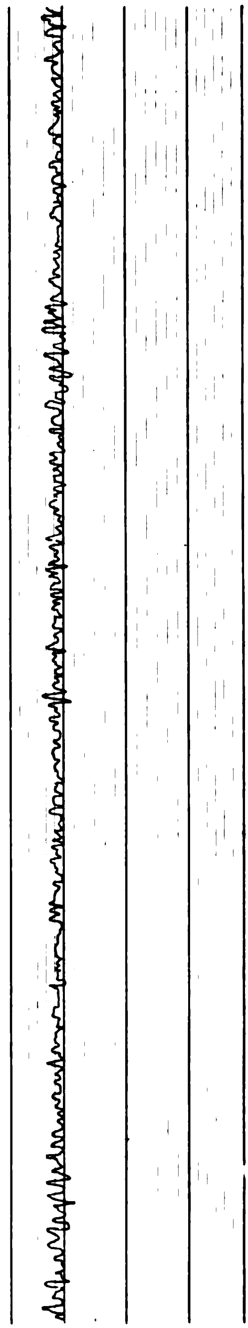


Fig. 27

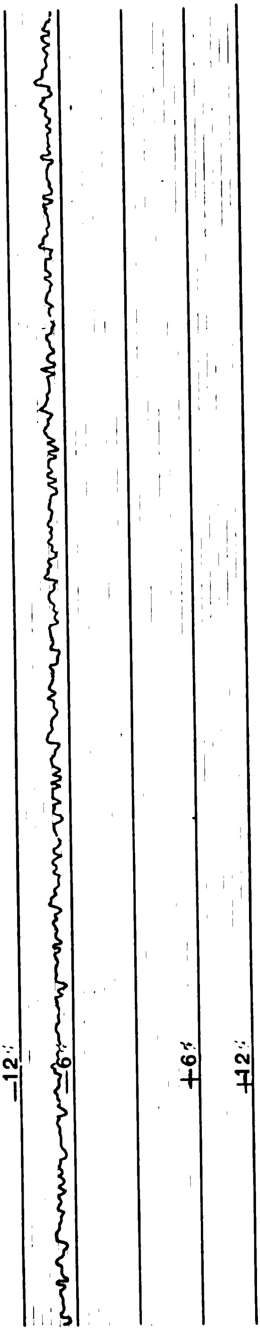


FIG. 28

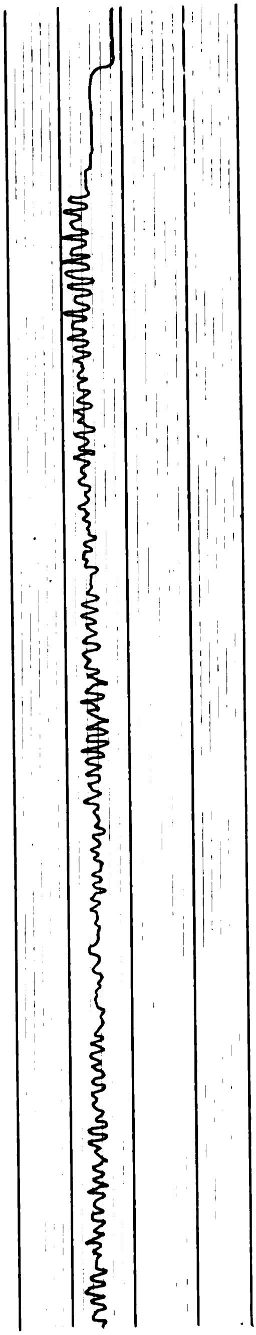


FIG. 29

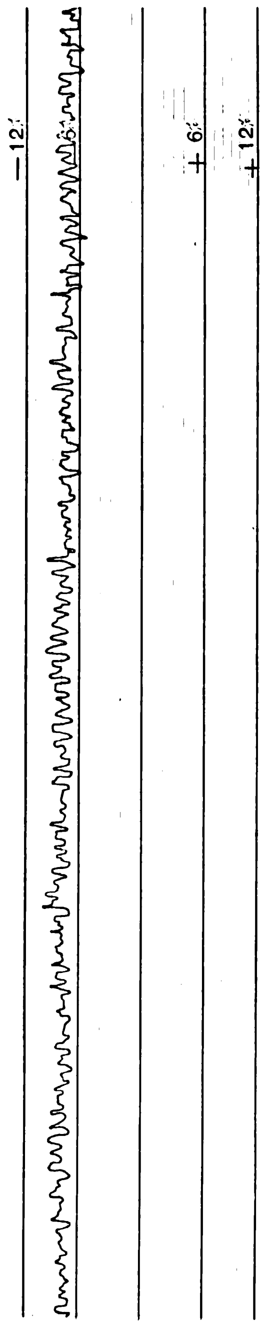


Fig. 30

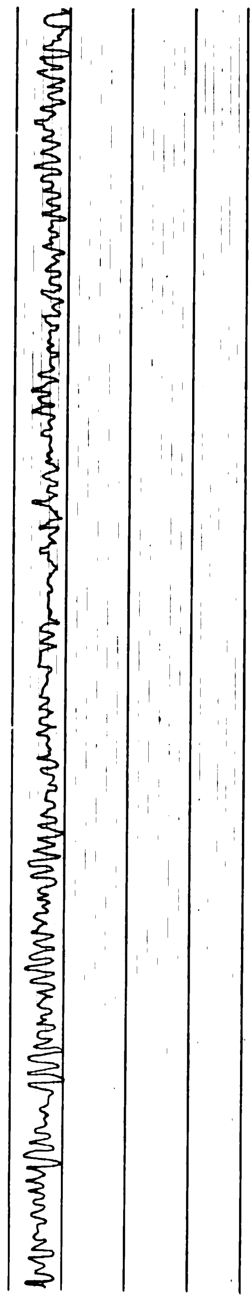


Fig. 31

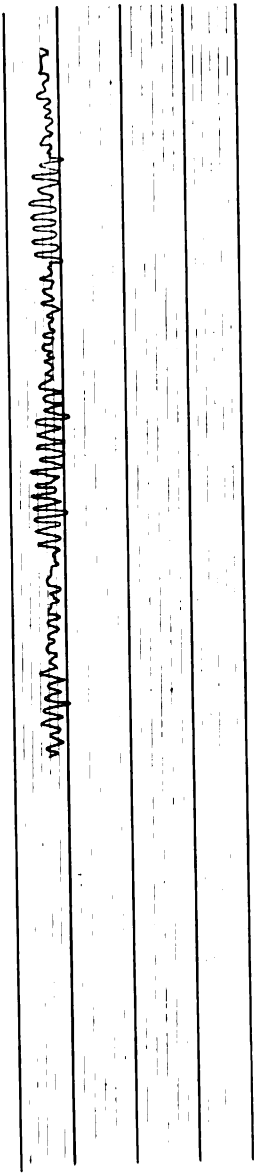


Fig. 32

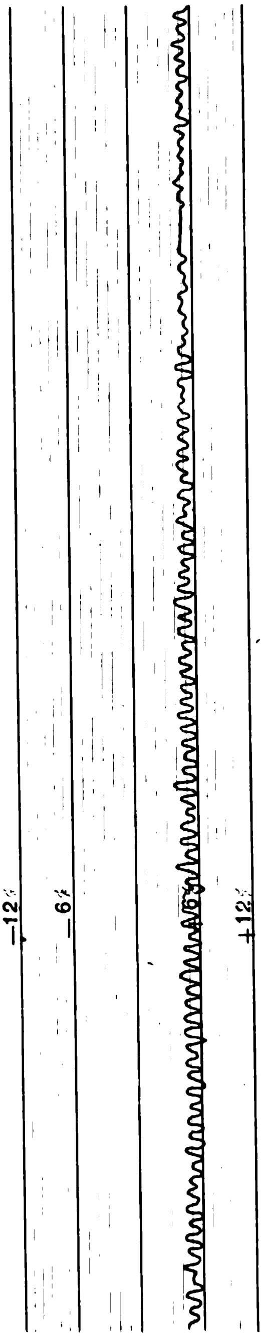


Fig. 33

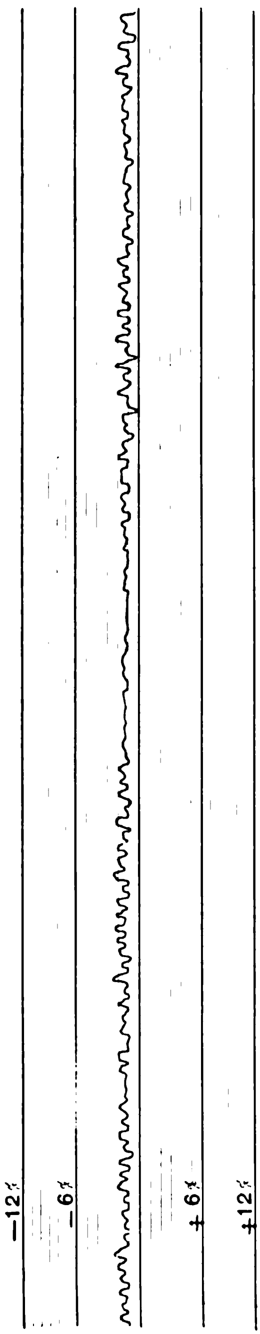


Fig. 34

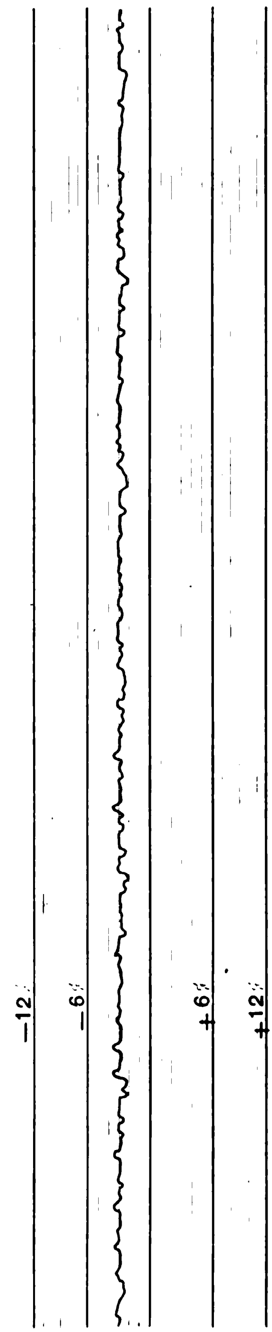


Fig. 35

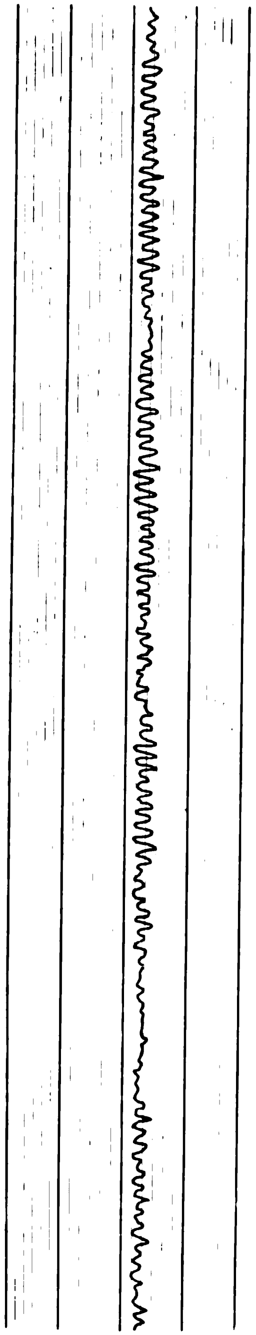


Fig. 36

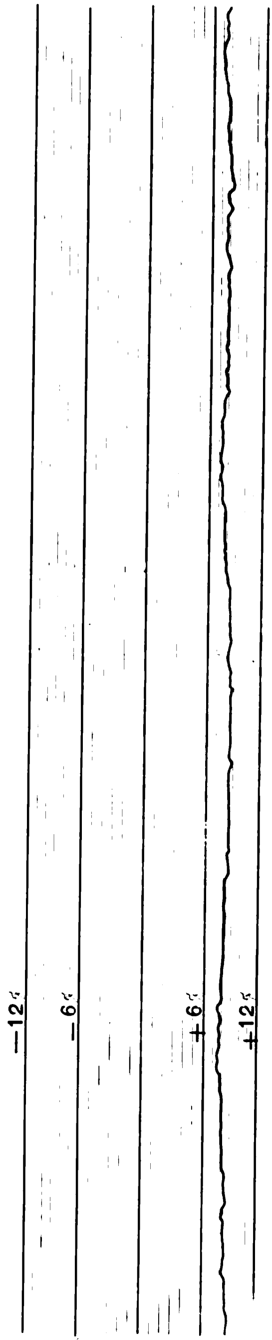


Fig. 37

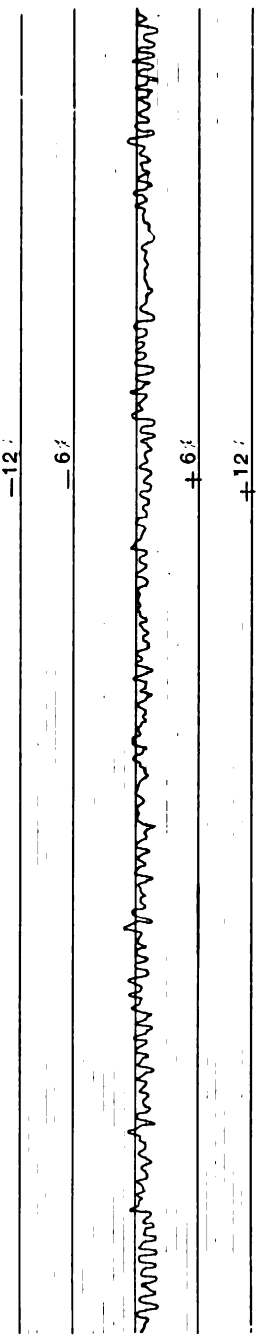


Fig. 38

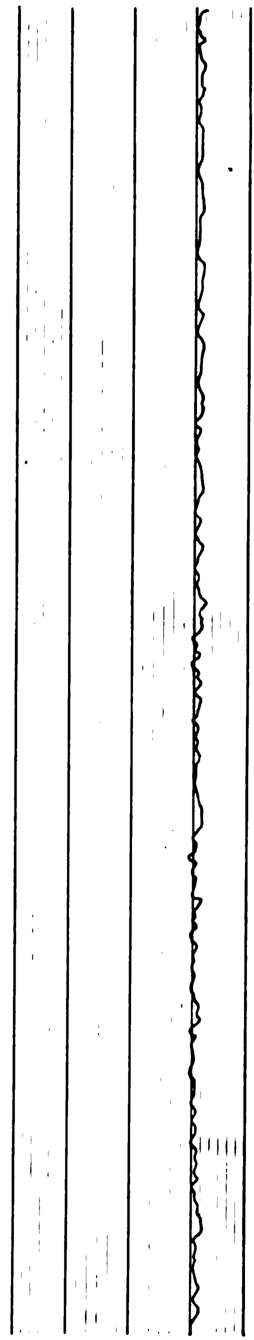


Fig. 39

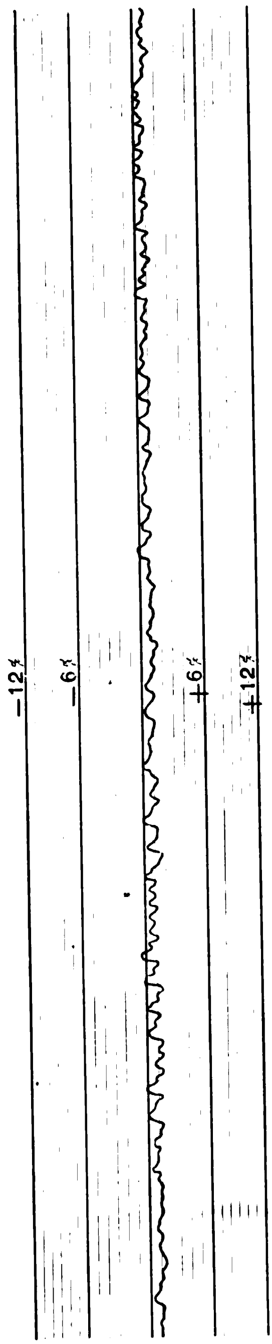


Fig. 40

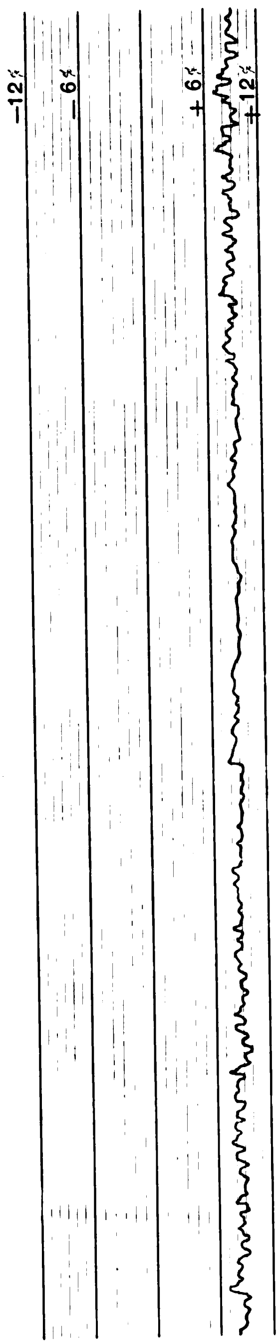


Fig. 41

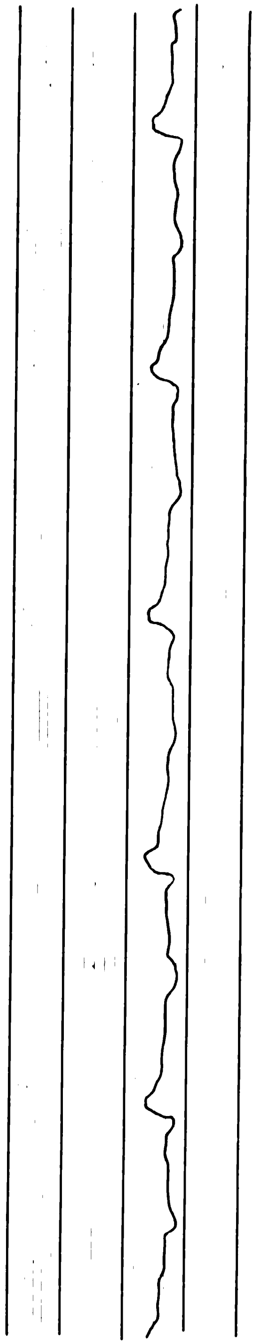


Fig. 42

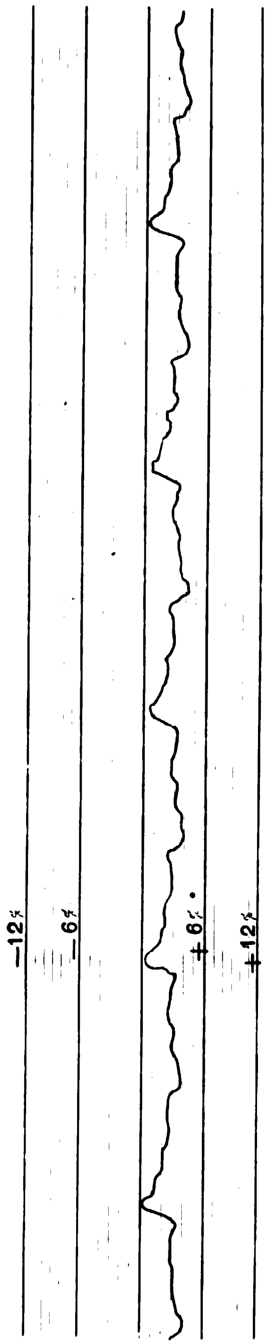


Fig. 43

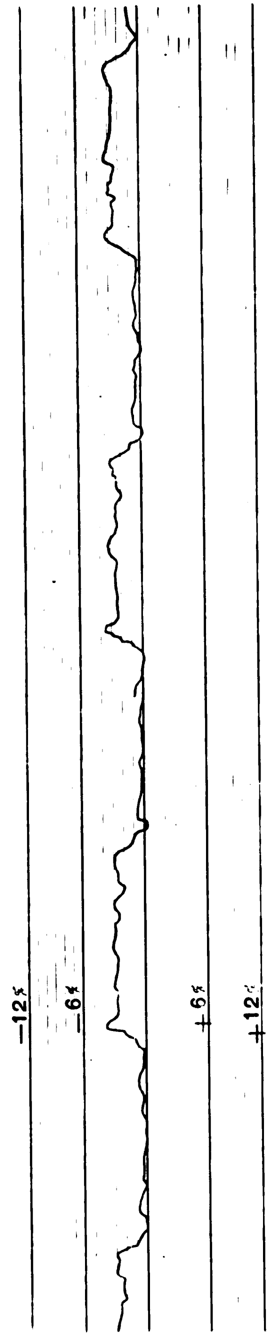


FIG 44

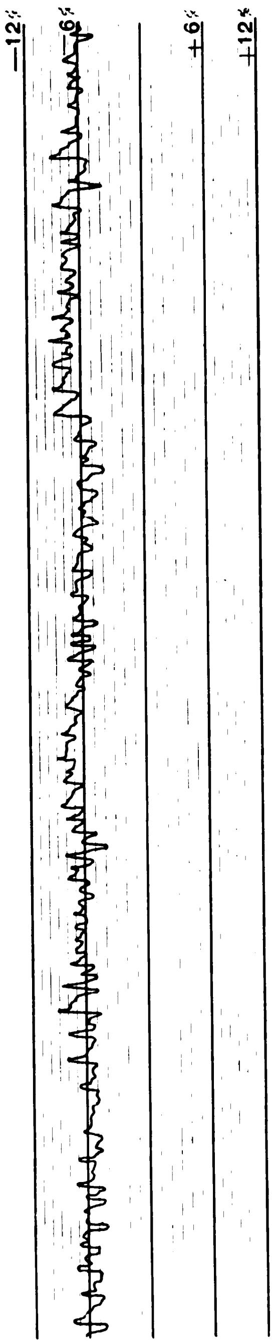


FIG. 45

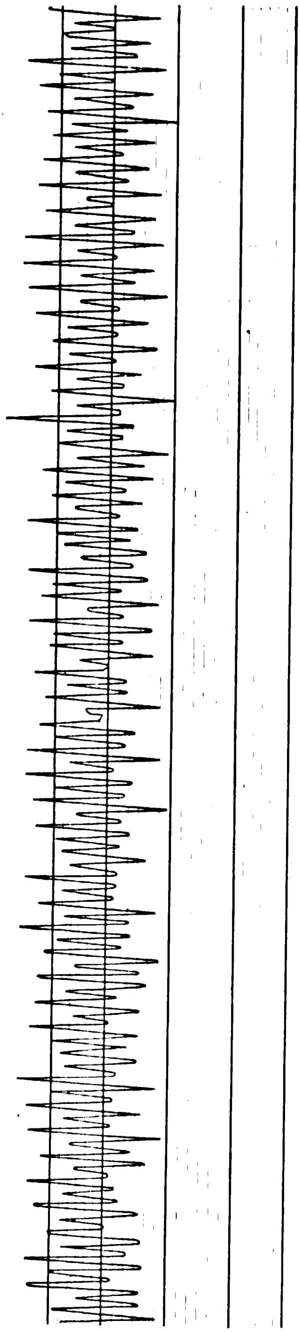


FIG. 46

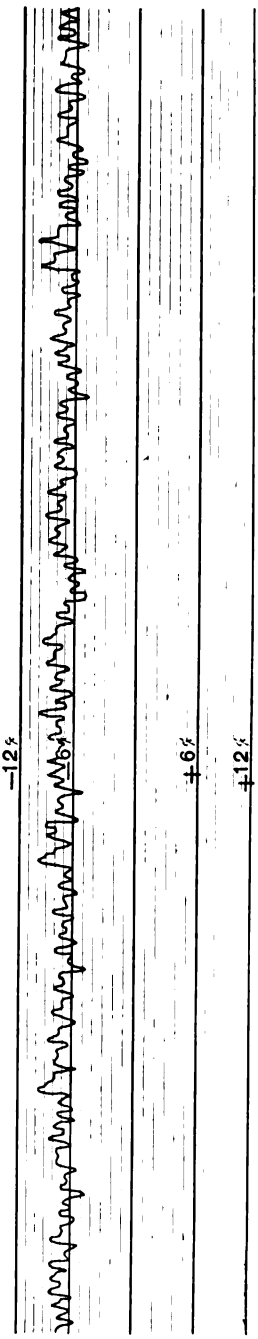


FIG. 47

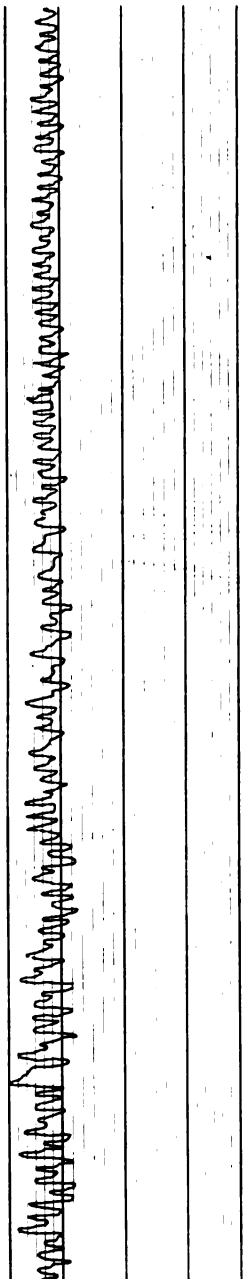


FIG. 48

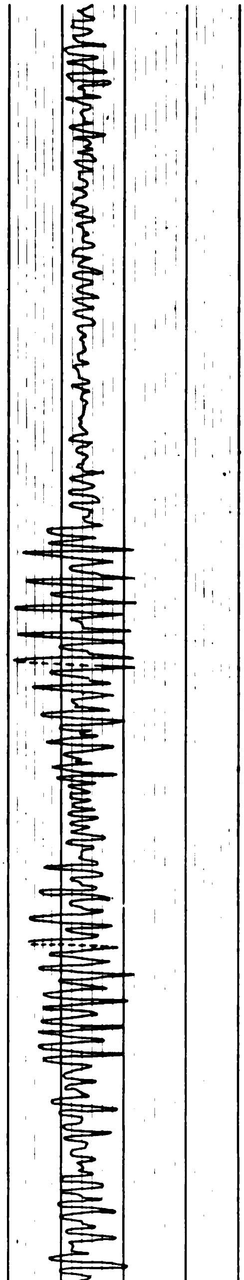


FIG. 49

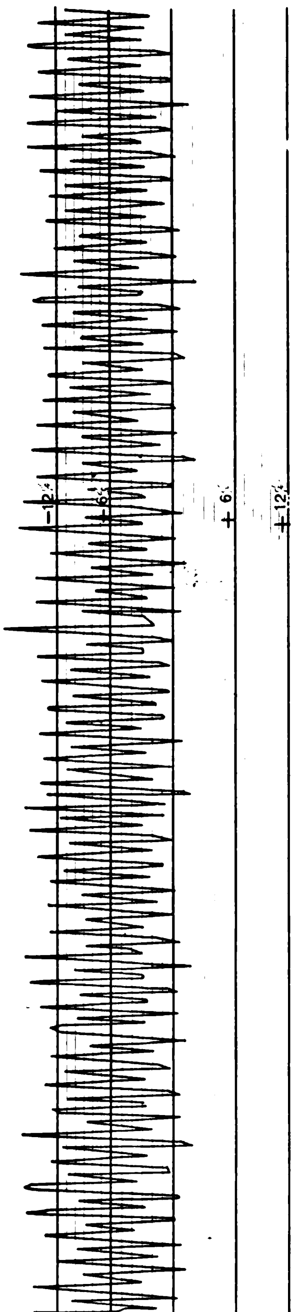


Fig. 50

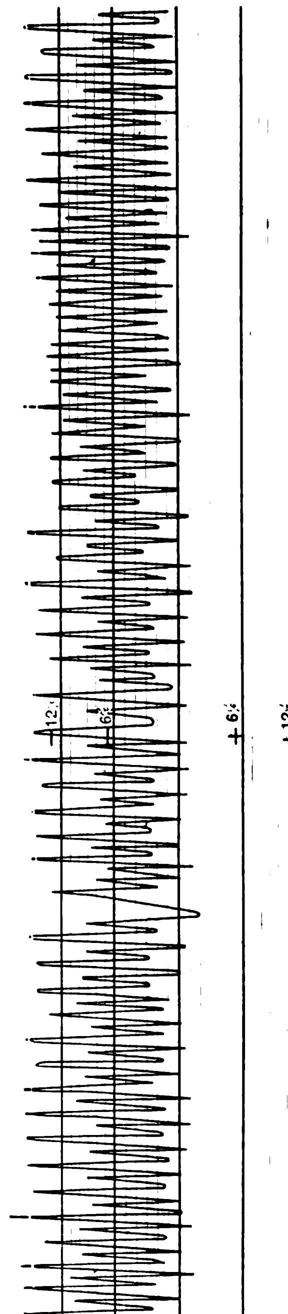


Fig. 51

These curves show the insufficiency of counted speeds where instantaneous variation is neglected. The highest point of the curve shows the maximum at which the work will run and all below that represents a loss of production. As a matter of interest the curves, Figs. 45 to 51, are shown. These illustrate an extremely bad speed condition of which the mill manager has been ignorant, and the mill has never been able to get out a good production.

In the territory of the larger hydroelectric systems the total number of mills operated consume a large amount of power. Each mill comprised in the group uses a relatively small proportion of the power furnished by the system. It is therefore possible to throw off or on many motors, or, indeed, many of the entire mills without disturbing the speed of the system. This is not the case in a mechanically driven mill, where even a small part of the machinery represents a good percentage of the total load of the engine.

In a converted mill, driven from a hydroelectric station, one of two results are always brought about. If the original production is maintained the amount of power necessary is reduced. This should not in all cases be regarded as of paramount importance, the most vital advantage being an increased product from the mill, which it has been shown can be obtained through electric drive. This has actually been obtained in nearly every case that has come under my observation.

In mills only very roughly converted, where surplus power is taken, and where the old uneconomical arrangement is left intact so that the steam drive may be used when the electric power is temporarily shut off, all carefully kept records show that an increase of production of from 2 to 10 per cent is obtained. In new mills especially constructed for electric drive the higher of these figures should obtain. This increase is brought about by two things. First, proper balancing of the work, and next, the application of motive power directly to the work it is to drive, and the fact that this motive power has a constant speed value, both instantaneously and continuously.

The importance of production may be shown in a broad, general way as follows: The value of a mill's product per annum is about equal to its capital stock. The cost of manufacture, with many variations for the class of work, may be taken proportionately about as follows:

Cotton, 60 per cent; power, 4 per cent; all other costs, 36 per

cent, and the power cost, as a total is from 3 to 6 per cent of the total market value of the product. Thus, assuming the cost of a 5000 spindle mill as \$100,000, its product in a year will be worth, roughly, \$100,000 and its power bills say \$5,000. If the product of this mill could be increased 10 per cent the gross value of this increase of product would be \$10,000 of which the only cost would be cotton and power and some labor. The most costly operations of labor are paid by the day and effect no increase.

Allowing, however, for some increased labor cost we have as the total cost of this extra production:

Cotton, 60 per cent; power, 4 per cent, and labor, 3 per cent, or a total of 67 per cent and a net profit of \$3,300 per year, or two-thirds of the total cost of the power, thus nearly eliminating the power bill. On account of the steadiness of the speed of the electric drive the machinery will suffer less deterioration than if run at even lower speeds with the steam drive.

It is very proper and very necessary to take all of these points into account as having a direct bearing on the cost of steam power.

General Remarks

Fig. 52 shows the increase in power furnished to textile mills in the Piedmont region of North Carolina and South Carolina by the Southern Power Company. It will be seen from this that the increase was very slight during the years 1904, 1905 and 1906. In 1907 the mill managements in the territory where these lines existed having had the experience of their neighbors over the years previously referred to, began to appreciate the advantages and economies of the hydroelectric drive. It will be noted from this curve that during the year of 1909 and especially the last six months this increase has been greater than at any other time.

In hydroelectric systems of distribution to cotton mills it is found to be impracticable to place a sub-station for each consumer, especially to meet the conditions which we have in Piedmont Carolina, where several mills of small or moderate size are installed in one town. This is on account of the large first cost of a substation reducing from 100,000 volts, and also on account of the difficulty of running the high-tension mains through cities and towns. On account of the high cost of transmitting low secondary voltage any distance, both as to initial investment and in power loss, it was found necessary to adopt 2200-volt

motors in mills where the general practice had been to use motors of 550, 400 and even as low as 220 volts.

At first considerable prejudice existed among the mill owners and the underwriters against the use of high voltage motors, but some years of experience have demonstrated their superiority in every way. The first cost is about equal to that of the lower

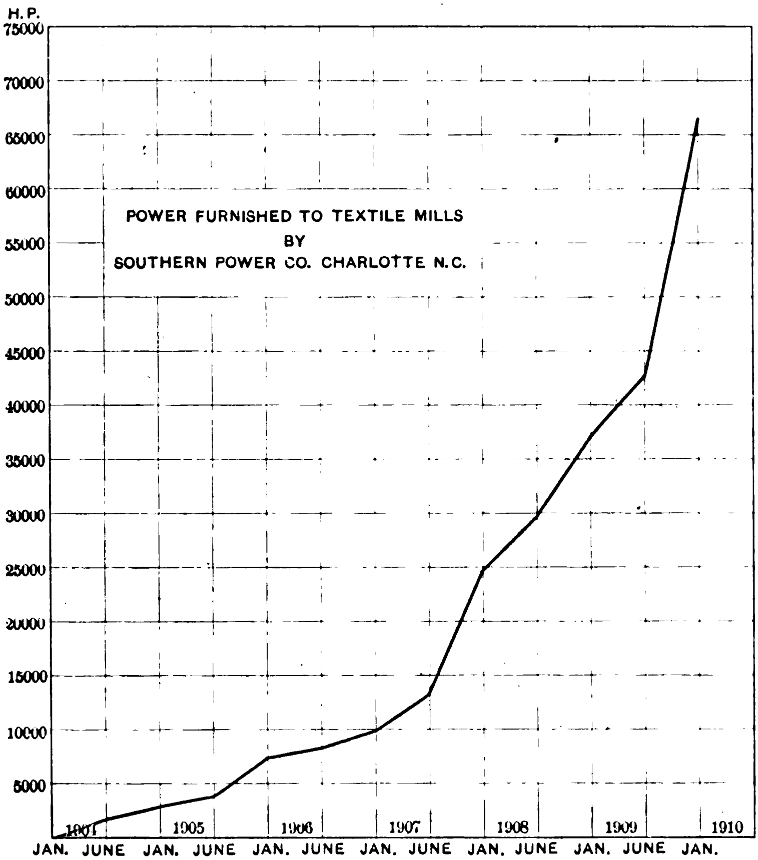


FIG. 52

voltage motors. Their efficiency is equal and the slip is also equal or somewhat less. With an equipment of 2200-volt motors power can be transmitted with an economical loss and reasonable first cost to a distance of approximately one and one-half miles from the central sub-station.

In many of the older low voltage installations, for the sake of

economy, open wire is run in the mill. The cost of installing it in conduit would be excessive on account of its size. And also on account of the size of the wires, and the very extensive system of feeders, it is only a matter of time until open wiring becomes disarranged, due to its being swept to remove the lint and dirt which it accumulates. Another serious feature of this system is the frequent and necessary employment of fuses to protect smaller branches.

Probably 90 per cent of the motors burned out in the mills under my charge have been burned out by the failure of one of the three fuses of the three-phase circuit, leaving the motor operating on a single phase, which eventually destroys it. On account of increases to the mill equipment, or bad initial calculations, the wiring loss in the mill often runs up to very high figures with the lower voltages. In one mill in my experience, with a 220-volt distribution about 500 feet long, the total wiring loss reaches 15 per cent, and this after the mill management had at a considerable cost added feeders from time to time as the mill has been enlarged.

In mills using 2200-volt motors, the wiring is run in iron or steel conduit and consists of three-wire insulated cable with lead sheaths. The loss in this system is reduced to practically nothing, the cost is low, and complete protection is afforded by means of automatic oil switches. The size of the wires is very small, and the whole system takes up less space in a mill and is no more conspicuous than water and sprinkler pipes. On account of grounding the conduit, the liability to accident is practically eliminated.

The manufacturers of standard motors now build 2200-volt motors in sizes of as low as 15 h.p., and where motors smaller than this are required, 2200 to 550-volt transformers are installed on the mill wall close to the motors and the secondary wire is run directly to the motors from them.

NOTE

The following paper is to be read at the 246th meeting of the American Institute of Electrical Engineers in **Charlotte, N. C., March 30 –April 1, 1910.** This paper is to be presented under the auspices of the Industrial Power Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **D. B. Rushmore, General Electric Co., Schenectady, N. Y.,** so that they will be received not later than March 28, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

GAS ENGINES IN CITY RAILWAY AND LIGHTING SERVICE

BY E. D. LATTA, JR.

It is not the object of this paper to present the subject of internal combustion engines from a scientific point of view, or to report on results obtained from tests made under the most favorable conditions with apparatus and facilities only to be found in an experimental laboratory, but to consider the subject under the following heads:

First, to give a description of the apparatus and equipment in a small but thoroughly appointed central station, viz: that of the Charlotte Electric Railway Company, using gas engines for prime movers, and supplying current for street railway purposes, electric lighting, and motors in small units.

Second, to give from the daily operating reports, some figures from which can be formed an idea of the reliability, efficiency, and adaptability of the plant under conditions which are relatively as severe as can well be imposed upon any plant, whether large or small. The extremely variable nature of a railway load and its rapid fluctuations caused by a system of few cars with comparatively large individual requirements, is so directly antagonistic to the fine degree of regulation and the continuity of operation demanded by good lighting service, that the handling of such conditions in a creditable manner should receive due consideration as a factor of no small importance.

Third, to give some data on the subject of producer gas manufacture, which to the engineer versed in the principles of fuel combustion may seem obvious and even crude, but which to operators and those investigating the operation of producer gas plants may be of value, in that it can be acquired only by

experience and by tedious reference to the works of many authors on the subject of fuel combustion.

Lastly, to offer a few remarks on the adaptability and advisability of gas engines for certain kinds of work.

The period covered by this paper, viz., twelve months, dates from the first of January, 1909, when the plant had been in operation for about six months, and could be considered as being fairly well under way. Much has been learned during the year just passed, and each day gives new experience for the operators. Therefore, while we feel satisfied and even gratified with the record to date, still we feel it is reasonable to expect an improvement over results of the present year, brought about by eliminating some of the petty troubles which experience has taught how to overcome, and thereby attaining a more uniform efficiency of operation.

Description of the Plant

The engine room equipment consists of two 810-b.h.p. horizontal twin-tandem, double-acting four-stroke cycle gas engines and one 60-h.p. single tandem exciter engine, in general similar to the large engines. The 540-kw., three-phase, 60-cycle, 2300-volt alternators, are direct and rigidly connected to the crank shafts of the main engines, and a 40-kw. direct-current generator is direct connected to the exciter engine. In addition to this apparatus there is an induction motor-driven exciter set of the same capacity as the engine exciter, a 300-kw. and a 500-kw. rotary converter, and the usual switchboard equipment.

The producer apparatus is contained in a building about one hundred feet from the power house, and consists of two 1000-h.p. units of twin generator down-draught producers, having a continuous overload capacity of 50 per cent. Each unit consists of two 9-ft. generators, 16 ft. high, having a fuel space 7 ft. in diameter by 8 ft. high above the grate bars, which are of arched fire-clay tile. The generators are connected at the bottom by openings, lined with fire brick, containing water-cooled gate valves, to an economizer or vertical boiler of 100 h.p. rating. From the top of the boilers a 16-in. pipe leads to the bottom of the wet scrubber and from the top of the wet scrubber to the exhauster, or through a by-pass around the exhauster to the dry scrubber. A 60,000-cu. ft. holder receives the gas from the producers and delivers it to the engines. (See cut of producer on page 494.)

To describe the engine more in detail, the cylinders are 24-in.

bore by 36-in. stroke; the fly-wheels are 16 ft. in diameter and weigh 34,000 lb. The entire engine occupies a floor space of 18 ft. by 44 ft. and together with the alternator weighs 500,000 lb. All parts of the engine that come in contact with the hot gases are water-jacketed, including cylinders, pistons, piston rods, mixing chamber, valves and valve seats, and the exhaust pipe down to the floor level. The jacket water from the various parts of the engine empties from separate pipes into open funnels, which enables the operator to determine at all times the temperature of the different parts of the engine.

The ignition is low tension make-and-break, with two igniters to each end of each cylinder. The ignition current is supplied by one of three batteries of five cells each, and requires about 10 volts. This current passes through a separate kicking coil to each igniter, and a pivoted armature at the end of each coil indicates when the igniter is working properly.

The valves are the poppet type and are actuated by bell-cranks which are lifted by cams on the cam-shafts which are geared to the crank shaft and run at half speed. While there are some mechanical objections to the use of cams on account of difficulty of lubrication, still they are supposed to have a decided advantage over eccentrics, which impart a harmonic motion to the valve. By the use of cams with properly designed contours, quick opening and quick closing of the valves is obtained, and there is a relatively long period during which the valve is wide open.

Intake and exhaust valves are located on top and bottom, respectively, of a compartment bolted to the side of the cylinder which acts as a mixing chamber at one time, and explosion chamber at another part of the cycle.

The governors are of the Jahns type, in which the centrifugal force of the weights revolving in a horizontal plane is resisted by the direct pressure of coiled springs, the weights turning on rollers in a constant oil bath which practically eliminates friction. The governor is driven by a belt from the cam-shaft, and carries no load other than that required to revolve itself. The cut-off valve shaft is driven by bevel gears from the cam-shaft through a hunting gear, which is raised or lowered by the governor, and thus advances or retards the motion of the cut-off shaft with regard to the cam-shaft. The cut-off shaft by means of cams serves all cut-off valves. A cut-off latch hook, engaging the cam of the cut-off shaft, releases the cut-off valve by means of a float-

ing lever connected to the inlet valve and latch which lifts the cut-off valve stem until the latch is disengaged. A dashpot on this valve stem permits the valve to close without jar.

The governing is done with a uniform mixture, the amount of which admitted to each cylinder being controlled by the governor through the agency of the cut-off valve gear. Each cylinder has its own separate mixing chamber and mixing valve which regulates the proportion of gas and air, and a disturbance such as a back-fire does not foul the gas going to other cylinders, this feature is a great advantage when close regulation is desired.

A plunger in the face of the fly-wheel works in and out radially against a coiled spring. In case of excessive speed of the fly-wheel, centrifugal force drives the plunger out beyond its normal position and opens a switch in the igniter circuit, thus shutting down the engine and preventing racing in case of the governor belt breaking or the governor otherwise losing control of the engine. This device is tested at regular intervals by depressing the governor, and is found invariably to operate within five or six revolutions above normal speed.

The problem of piston packing which for many years was one of the greatest difficulties in the way of building double acting engines has been solved in a fairly satisfactory manner by the use of metallic packing contained in packing cases. The packing cases each contain five rings of special cast iron made in segments, with overlapping joints, the segments being held in place against the piston rod by a 3/16-in. garter spring drawn around the circumference. The packing case is bolted to the cylinder head by means of a flange, between which and the cylinder head is a ground joint. About once a month each packing case is removed and supplied with clean packing. The packing removed is then thoroughly cleaned when convenient and put aside for use at another time. If a high grade cylinder oil is used and the packing is regularly cleaned, the troubles from this source are practically eliminated.

The pistons are about 24 in. long and each has six slots in which are cast iron piston rings. The clearance between rings and slots is 12/1000 in. This clearance should be very carefully determined for different engines, as it depends principally upon the kind of gas used, and the nature of the lubricating oil. If the clearance is too small and the gas is not clean or the oil is inferior, the rings will become carbonized and stick in the slots. On the other hand, if the clearance is too great, a hammering

action will take place between the rings and slots, and both will become badly battered in a short time. The joints in the rings are staggered and all joints are made at the bottom of the piston. The clearance between the bottom of the piston and the cylinder wall is very small, 11/1000 in. so as to reduce to a minimum the slippage past the piston.

Three cross-heads, one between the cylinders and one at the end of each cylinder, carry all the weight of piston and piston rod, relieving the cylinder walls and maintaining the piston rod in alignment.

The lubrication of the main bearings is accomplished by a flushing system of oil operated by turbine pumps, attached to the engine, which carry the oil from the engine through a filter to an elevated tank whence it returns by gravity.

The cylinders are lubricated by multiple pumps positively driven from the cam-shaft, the plungers of these pumps being so timed as to inject oil on the piston at the end of each power stroke.

Two air tanks each 5 ft. in diameter and 10 ft. long, located in the basement of the engine room, are kept charged with air at 150 lb. pressure for starting the engine. This air is delivered to the engine by two distributing valves driven by the cam-shafts, and so timed that air is admitted to each cylinder at the beginning of its power stroke. The compressed air is supplied by two compound steam pumps controlled by automatic governors, the pumps being located in the producer house.

During the summer months about 15 gallons of water, at an initial temperature of 80 degrees fahr., is required per horse power-hour for cooling, the temperature of discharge being about 120 degrees. During the winter months 10 gallons of water per horse power-hour at 60 degrees is sufficient, and it is discharged at about 100 degrees. The difference in the amount of water required in summer and winter is apparently due to the fact that the heat lost by radiation is much greater in winter. Even in the coldest weather that has been experienced since the plant has been in operation no other heat has been required for heating the building, and the temperature has not been found uncomfortable at any time.

The jacket water after being discharged from the engine flows by gravity to a hot well (see Fig. 1) of the cooling system, from which it is drawn by an electrically driven centrifugal pump of 50,000 gallons per hour capacity, against 15 lb. pressure, and

forced through sprays into a basin in the middle of which is a cold well. From the cold well it is taken by a two-stage turbine pump of 15,000 gallons per hour capacity against 30 lb. pressure, and returned to the engine. These pumps are driven by the

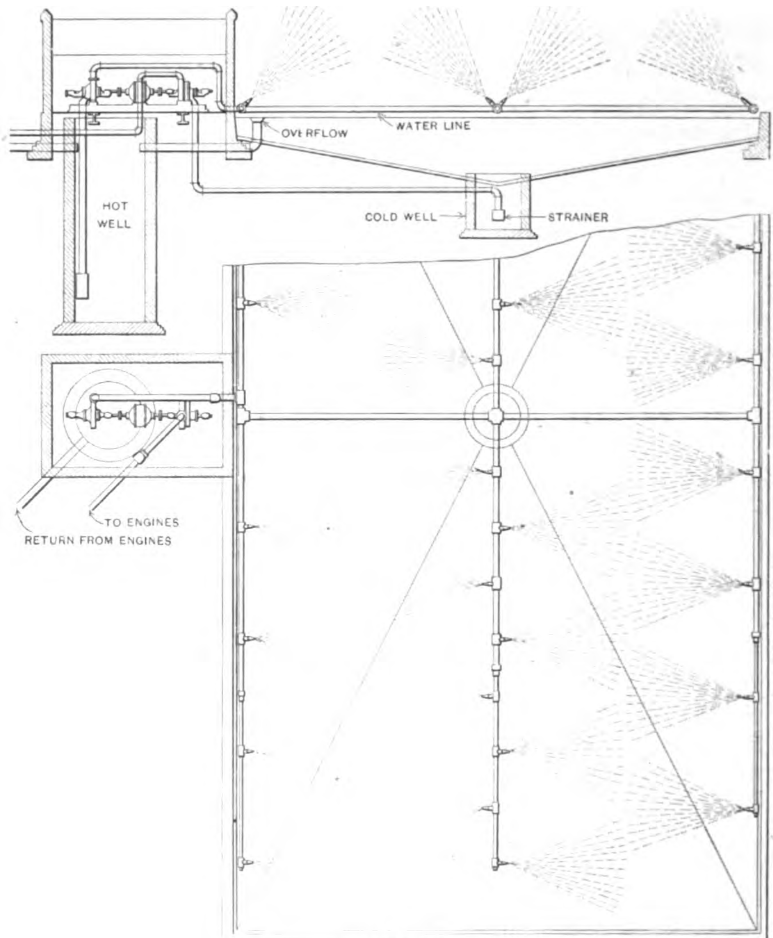


FIG. 1—Cooling system for jacket water of gas engine plant

same motor. As the capacity of the single-stage or hot-well pump is three times as great as that of the cold-well pump it follows that an excess of water is sprayed into the basin over that taken out of the cold well; this excess water overflows and returns to the hot well where it is again pumped through the

sprays. In this way all the water passes through the sprays three times to each time it is used in the engine and ample cooling is obtained, the water in the cold well being reduced to a temperature slightly below that of the atmosphere. The loss in water by evaporation to attain this degree of cooling is about 10 per cent, although in windy weather there is a slight additional loss occasioned by the blowing away of the spray.

Unlike a steam engine cutting off at 20 per cent to 25 per cent of its stroke for most efficient operation, permitting the steam to expand during the remainder of the stroke, a gas engine's most economical point of operation is attained when a full charge of the gas and air mixture is admitted to the cylinders. This condition is due to the following causes:

First, the combustion of gas is so rapid, that almost complete combustion takes place before the piston has moved but a little distance away from the end of the cylinder. The initial expansion therefore takes place at practically constant volume, the excessively high temperature of the gas burning in a restricted area causing an extremely rapid transfer of heat in the early part of the stroke.

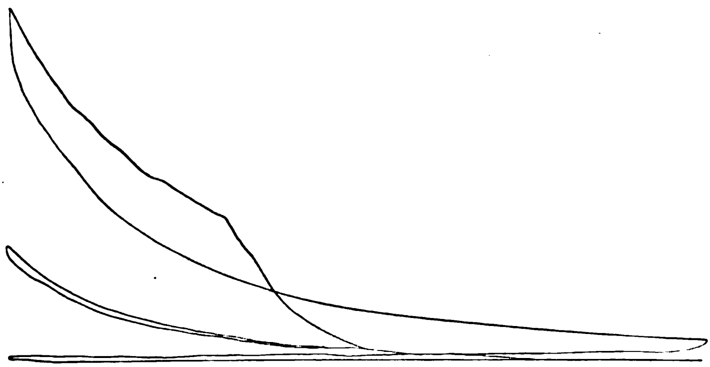
Second, it has been found by experiment that inflammable gases ignited in the presence of oxygen, at constant volume, reach almost instantly a maximum temperature and consequently maximum pressure, and fall within a small fraction of a second (about 1/10 second) to a point far below the maximum, after which the pressure remains constant provided there is no transfer of heat. As one-quarter second is required for the full travel of the piston in one of these engines, it is clear that this rapid decline in pressure takes place before the piston has reached the middle point of its stroke. Both of these conditions largely reduce the expansive work of the gas.

Third, the percentage of inflammable gas contained in a charge of the mixture is small (about 32 per cent), the balance of the charge consisting principally of nitrogen and a small amount of carbonic acid gas, both of which are inert and absorb heat from the combustible constituents. It therefore requires a relatively large intake of the mixture to contain a sufficient amount of active gas to produce a given amount of power.

Under the foregoing conditions it follows that if a gas engine were rated at its most economical load, it would have no overload capacity whatever, but to obviate this condition it is customary to arbitrarily rate a gas engine at 87 per cent of its ultimate

continuous capacity, which rating permits of an overload of 15 per cent. In the case of these engines, which are rated at 810 b.h.p. we have frequently carried a load of 700 kw. which is equal to 1010 b.h.p., or nearly 25 per cent overload for a considerable length of time, and a momentary load of 800 kw. or 42 per cent over load without reducing the speed to a point that caused any trouble. While it would appear from these figures that the engines are somewhat under rated for continuous operating, the 15 per cent overload is as much as should be put upon them. The load of 700 kw., although it does not reduce the speed materially, gradually heats up the engine, with the result that after a few hours operation preignitions occur; also the high pressure in the cylinder strains the packing and causes gas to blow through.

There are three classes of disturbances that take place in-

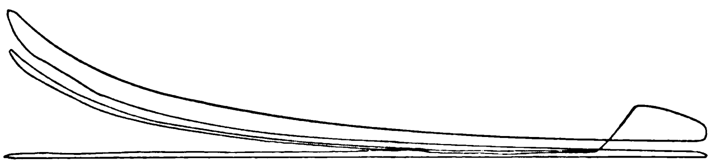


INDICATOR CARD No. 1—Preignition

frequently in these engines, as is the case with all gas engines, viz: preignition, back-fires, and muffler explosions. The first of these is caused by the use of gas over rich in hydrogen, which ignites very readily under high compression without other application of heat; also by particles of carbon or other solid matter which become lodged in the cylinder and become incandescent under the temperature of compression, or when any of the water-cooled parts of the engine are insufficiently cooled by using too little water, or water at too high temperature. Preignition means that the gas becomes ignited during the compression stroke and the burning gas instead of being relieved by the forward motion of the piston as is the case in a power stroke, continues to be compressed until the piston reaches the end of its travel, with the result that back pressure of an extremely high degree is developed

which momentarily tends to reduce the speed of the engine. Indicator card No. 1, taken at time of preignition, is shown herewith.

A back-fire occurs when the gas admitted to the cylinder is ignited on the suction stroke, but can also be caused by a leaky inlet valve, in which case the gas in the inlet pipe is ignited during the explosion stroke. Ordinarily a back-fire is caused when gas of a too lean nature is used, so that the gas burns very slowly and continues to burn in the exhaust stroke. A part of the gas still burning in the clearance space ignites the incoming charge. Also if there are any pockets or small passages, such as the water-cooled pipe leading to the indicator cock, the gas in the passage or pocket is cooled to a point where it does not ignite readily. It becomes heated and ignites in the latter part of the pressure stroke, and continues to burn until the succeeding intake stroke when the incoming charge is ignited. The result of a back-fire is only the loss of the next power stroke, and usually a mis-fire



INDICATOR CARD No. 2—Back-fire

at the second succeeding power stroke caused by the burning gas blowing back into the intake pipe and fouling the gas contained in it. Back-fires were at first very common with these engines and were caused by a short section of water-cooled pipe leading to the indicator cocks, these pipes were removed, and a different type of indicator cock supplied. In the new type, the valve of the indicator cock seats directly against the outside of the cylinder wall and there is, therefore, no pocket to retain the gas, and back-fires very seldom occur. Indicator card No. 2 shows the result of a back-fire.

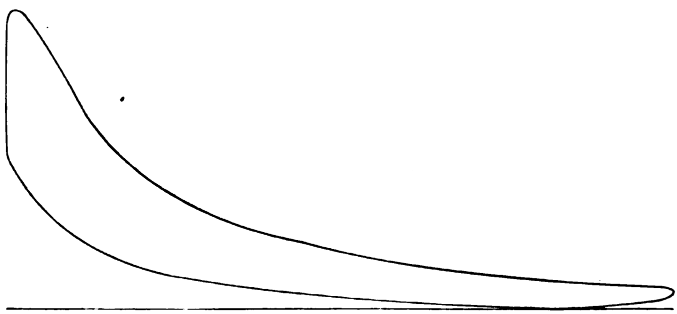
The disturbance caused by preignitions and back-fires is only momentary, and even when the engines are operating in parallel very little effect can be noticed.

A muffler explosion is caused after a mis-fire, when an unburned charge of gas and air passes into the exhaust pipe and is ignited by the exhaust from the power stroke of another cylinder. It has no effect upon the operation of the engine, but makes a noise similar to that of a preignition or back-fire.

Mis-fires seldom occur except following a back-fire as explained above. The double system of ignition practically obviates the possibility of this trouble.

Indicator card No. 3. is a typical gas engine card. It was taken, as were Nos. 1 and 2, with a 150-lb. spring. The compression is 135 lb. and the explosion pressure 267 1/2 lb. The mean effective pressure, as taken with a planimeter, is 53.625 lb. per sq. in., which would develop 311 h.p. per stroke in this one cylinder. As there are two cylinders acting during each stroke, the total indicated horse power of the engine at the moment the card was taken should have been 622 i.h.p. The load observed on the wattmeter at this moment, however, was rising, and was something over 600 kw.

Card No. 4 is taken at light load with a 16-lb. spring; one complete cycle and part of another is shown on the card as follows:



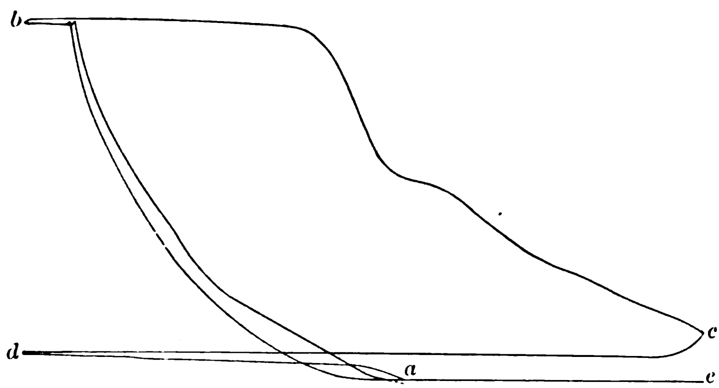
INDICATOR CARD NO. 3—150-lb. spring; compression 135 lb; explosion pressure 267.5 lb.; mean effective pressure 53.625 lb.

a to *b* last half of compression stroke, *b* to *c* combustion or power stroke, *c* to *d* exhaust stroke, *d* to *a* to *c* suction stroke, *e* to *a* to *b* compression stroke. At *b* the pencil was lifted. At *a* on the suction stroke the cut-off valve at the inlet closes, and the vacuum increases to a point below the range of the indicator, also at *b* the pressure reaches the other extreme limit of the indicator where it remains until expansion reduces the pressure to a point within the range of the light spring. A card taken with a light spring, as in this case, is of value in that it shows more distinctly than cards taken with a heavier spring the opening of the exhaust valve, and any wear of the cam operating the exhaust valve would be clearly shown by the toe of the card.

Improper action of a gas engine is not shown nearly as clearly by the indicator card as it is in the case of a steam engine. For

instance, the exhaust valve of a gas engine might be leaking and the only indication of the trouble would be low compression, yet the low compression might be caused also by badly worn piston rings or by packing in bad condition. The principal value of the indicator card is in adjusting the proportion of air and gas to give the most effective mixture, and for properly timing the ignition.

To adjust the mixture it is desirable to put a steady load upon the engine, preferably that produced by a water box, and then indicate the engine and adjust the mixing valve until the card shows the maximum explosion pressure for a given compression, which is the condition existing when sufficient air for complete combustion is admitted with the gas, without excess. When



INDICATOR CARD No. 4—16-lb. spring

once adjusted for gas of a certain quality it is not necessary to change the mixing valve again.

The indicator is most frequently used for timing the ignition, which can be done with precision in no other way. This becomes necessary at regular intervals on account of wear, both mechanical and electrolytic, of the igniter contacts. From time to time the igniters have to be taken out, cleaned, and the contact points smoothed up, and in replacing the igniter after this overhauling, cards are taken from this cylinder, and the tappet rods which control the make-and-break movement are adjusted so that the card shows proper ignition.

The diagram herewith, Fig. 2, shows the various events of valves and ignition during one cycle, or two revolutions of the fly-wheel. It will be noted that the valves open a number of

degrees before the dead center, and close 10 degrees after passing the dead center, while the periods of suction, compression, combustion and exhaust begin and end exactly at the centers. The reason for this apparent discrepancy is that the movement of valves is so very rapid, that a certain time element is required to accommodate the slower movement of the gas. The points indicated as valve openings and valve closings on the diagram, represent the points at which the valves begin to open and are completely closed. As the opening and closing of the valves require an appreciable length of time, the actual period during

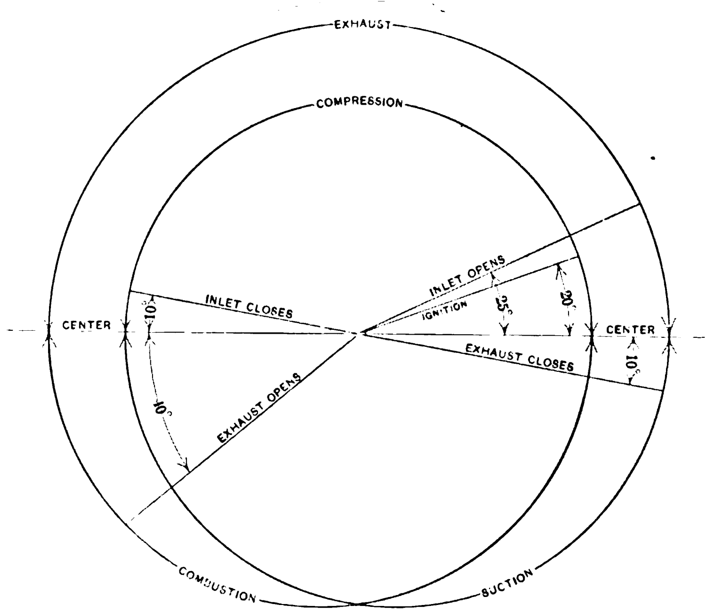


FIG. 2—Valve diagram of four-cycle gas engine

which the valves are wide open more nearly coincides with the period of travel of the piston. It will be understood that the cut-off valve is released independently of the inlet valve closing, and may occur at any point of the suction stroke, depending upon the load.

While the ignition is shown to take place at a point 20 degrees ahead of the end of the compression stroke, this location of the ignition is only approximately correct, for, as explained above, the position is located in practice by means of the indicator, and it may vary slightly with the quality of the gas and propor-

tion of mixture. The ignition is timed to occur 20 degrees before reaching the end of the stroke, so that sufficient time will be given for the flame propagation before beginning the power stroke. The ignition of these engines takes place in a combustion chamber just off the end of the cylinder. When the gas in the combustion chamber becomes thoroughly ignited, it bursts out into the clearance space of the cylinder, practically at the time the piston is at the end of its travel, the molecules of gas are compressed to the highest degree, and the flame from the combustion chamber ignites it almost instantly. The flame propagation about the igniters is in spherical form, the surface of the sphere increasing as the square of the time elapsing after ignition. In the combustion chamber, therefore, the time required for the entire volume to become ignited is appreciable. The gas in the cylinder, however, is ignited by the flame from the combustion chamber and from the indicator cards it seems to be practically instantaneous.

To develop full power on the engine it is necessary that cylinder and pistons should be perfectly tight, for not only is power lost by leakage past the piston and through leaky valves on the power stroke, but poor compression of the gases will mean slow ignition and a considerable loss in initial pressure. In order that ignition should be rapid, the molecules of gas must be closely pressed together so that the initial pressure will be high, and if timed so as to reach the maximum point just as the piston starts to move forward, the full power of the gas will be developed.

Plant Performance

Under this head, considering the class of service, we regard reliability as being of paramount importance, and we believe the record, taken from the engineer's daily log, of shut-downs caused by gas and engine troubles only, will be considered extremely creditable when allowance is made for the severe conditions of operation, and the fact that the plant was only in its first full year of existence. Electrical troubles have been decidedly more annoying than engine troubles, but such of these as have no bearing whatever upon the engine or gas operation will not be mentioned inasmuch as they are irrelevant.

From the daily reports we find, as follows :

Jan. 1—Exciter spark plug out of order.......... 5 min.
Jan. 31—Exciter trouble.......... 5 min.
Feb. No trouble.
Mar. No trouble.

April 12—Plant shut down caused by suction of engine drawing water from the gasometer over into gas main, causing water trap and shutting off gas supply. . 45 min
April 27—Same trouble..30 min.
At the first occurrence it was not known exactly what the source of this water was, and it was attributed to condensation from the gas, but after the second occurrence the trouble was located, and corrected by raising the inner walls of the gasometer, and making the lift necessary to draw the water over the top greater than the suction from the engine could accomplish.
May—No trouble.
June 18—Shut down at one o'clock a.m. caused by belt on oil pump breaking; the other engine was undergoing some slight repairs and was not in condition to start..15 min.
July 23—Shut down on account of igniter wire from battery to engine becoming grounded in conduit. This trouble, although located promptly, could not be repaired without great delay, therefore wire had to be run across engine room floor and old wire cut out...45 min
July 30—Shut down caused by operation of safety stop on engine, opening igniter circuit...12 min.
Aug.—No trouble.
Sept.—No trouble.
Oct.—No trouble.
Nov.—Shut down caused by unusual overload occurring when only one engine was in operation... 8 min
Dec.—No trouble.
Total interruption of service due to gas and engine troubles........2 hr. 45 min

In considering these figures it should be borne in mind that the plant operates 24 hours per day and every day in the year.

Other troubles have occurred while both engines were operating, making it necessary to carry the entire load, or the principal part of it, on one engine, but while these occasions caused annoyance, they were handled without serious inconvenience to service.

Second in importance to reliability we regard character of operation, viz: speed regulation, and ability to operate successfully in parallel, the former being a function of the engine only, while the latter involves both engine and alternator.

The manufacturers guarantee as to speed is, that from 25 per cent to full load, the engine will govern within a maximum variation of 2 per cent. This condition is met as regards the mean speed on steady loads. When, however, a heavy load is suddenly thrown on the engine, or removed from it, a momentary swing of not exceeding 2 per cent below or above mean speed for the given load occurs, which is due to overreaching of the governor. While this swing in speed is not excessive, and is found to an equal or even greater extent in high-class reciprocating steam engines, it is rather remarkable that it is not far worse than the above figure in a four-cycle gas engine; for at the moment the load on the engine is changing, the governor has no control whatever upon the charge of gas next to be ignited, since the amount of this charge was regulated in the suction stroke which preceded the compression stroke. For example, assume

that the engine is operating at three-quarter load, and the governor by means of the cut-off valves is regulating the amount of gas per charge accordingly; just as one crank reaches dead center and ignition has taken place prior to a power stroke, an additional load is thrown on the engine, making a total load equal to the full capacity of the engine; the cylinder for the next power stroke just ignited is charged with gas for three-quarter load, the cylinder on the other side of the engine is midway of the compression stroke, and is therefore beyond the influence of the governor, and the cylinder on the same side of the engine as the one just ignited is just completing its suction stroke and has been cut off at 75 per cent of the stroke, rendering it, also, out of reach of the governor. We have therefore three impulses of power strokes of three-quarter value before a full load charge of gas can be admitted to the engine, during which time the fly-wheel has turned 270 degrees, and it would be expected that the governor would continue to drop and overreach before corrected by the increased speed from full power strokes. This natural tendency to over-reach on the part of the governor, is reduced to a minimum however by the nice adjustment between the fly-wheel inertia and damping of the governor.

It is generally supposed that the turning moment or angular velocity of a gas engine is uneven and characterized by periodic variations with each impulse, due to the fact that the initial cylinder pressures are extremely high as compared to those of steam engines. This would no doubt be the case with a single-tandem, four-cycle gas engine, but with the twin-tandem engines having four double acting cylinders, eight impulses are given to the fly-wheel in two revolutions or one complete cycle. Therefore, as the cranks of the two sides are quartering, an impulse is imparted to the fly-wheel every 90 degrees, or two impulses per stroke. The impulses thus over-lapping tend to smooth out the variations that otherwise would occur, and permit of a far lighter fly-wheel than could be used with a single-tandem engine. The lighter fly-wheel is less sluggish and consequently promotes good parallel operation, but it is not too light to afford sufficient inertia to practically absorb the variations in crank effort.

We have been convinced of the correctness of this statement by observing the behavior of the alternators at various times when they were running in synchronism, with the engine cranks in almost every possible relation. No difference can be discerned in the action of the switchboard instruments, whether the cranks are in step or in any other possible position.

While the parallel operation of this engine would not be considered good in comparison with steam turbines operating at high speed, with alternators having from two to four field poles, it nevertheless compares favorably with the best type of reciprocating steam engines with alternators having the same number of field poles, viz., sixty, which of course means that the variations in electrical degrees will be thirty times as great per degree of angular variation as would be the case in a turbine of the same capacity, which would operate at 3600 revolutions per minute.

The temperatures of the alternators above room temperatures, so far as can be observed with the constantly varying load, do not indicate an excessive synchronizing current, and there has never been any tendency on the part of the synchronous converters to fall out of step. The smaller converter running from one engine or from both in parallel, shows no signs of hunting, neither does the 500-kw. converter when running from both engines in parallel. It, however, hunts slightly when running on only one engine. This is probably due to the fact that this converter is practically of the same capacity as the one alternator, and the fly-wheel effect of its rotor is too great to permit its conforming to the variations of speed which are greater for a given load with one engine operating alone than when both are in parallel.

There is a slight periodic swing between the pointers of the wattmeters when the engines are operating in parallel; this is no doubt accentuated by the extreme sensitiveness of the meters, which have 325-degree scales, and by the pendulum motion of the pointers which is common in instruments of this kind. The same swing appears on the ammeters, but to a much less extent. The engines divide the load very equally, and by adjusting the governors they can be made to divide the load in any proportion that may be desired.

Below are shown four speed curves taken with an extremely sensitive graphic recording speed indicator. Each ½ in. of length represents approximately a time interval of one second, and the spaces between lines represent variations of one per cent.

The first record was taken from an engine with no load, and the second was taken from one engine with the load varying from 300 to 500 kw.

The third record was taken from one engine in parallel with the other engine under a total load ranging from 300 to 500 kw.

The fourth record is taken from one of the two engines in

parallel, with a load of 300 to 500 kw., and a load of 600 kw. thrown on and off.

Cost of Operation and Repairs

The figures given below covering the cost of operation and repairs speak for themselves, and there is little further to be said except to call attention to the extremely low load factor which is the controlling condition. The poor load factor is due principally to two conditions; first, the prevailing load for twenty hours per day is easily within the range of one unit, but the wide limits of variation make it necessary to operate the second engine on an average of ten hours per day; and second, from 12 o'clock night until 6 a.m one engine operates on practically no load at all.

We do not claim high economy for this plant, and can hardly expect it under the circumstances, and while we hope in future to effect a slight reduction in coal consumption by a more consistent and economical operation of the producers, we cannot expect a material improvement in operating cost under the load conditions that obtain.

We estimate that with an increase in the load factor of 25 per cent the additional output could be produced for an amount not exceeding 10 per cent of the present cost, because a higher economy of coal would result from a higher load factor, with practically no increase in labor, water, oil, or other of the larger items that go to make up the total cost.

In the matter of cost of repairs, also, we expect a reduction rather than an increase in the near future. The largest item in the total cost of repair parts is the cost of an entire new equipment of exhaust valves, which amounts to about half of the total. These exhaust valves were put in, not on account of wear and tear, or breakage of the original ones, but on account of their inferior design, which caused them to continually work loose from the stem, which was connected by a flange and stud-bolts. The new type has proved entirely satisfactory.

Four pistons have been taken out and fitted with new rings, the original rings having become broken when water leaks occurred in the cylinders due to defects in the castings of the piston water compartments. Broken rings almost invariably result from water leaks in a cylinder. In this case, new parts were furnished by the manufacturers without charge, and the labor was furnished principally from the operating force.

Considerable annoyance, though only slight expense, has been occasioned by the backing off of the packing glands around the valve stems, caused by vibration, and a consequent breaking of the exhaust valve casing. This trouble could have been avoided in the beginning, as it has been since, by tapping set screws into the packing glands to prevent their working loose.

The least serious trouble that has been encountered, but one of the most annoying, on account of its occurring at most inopportune times, is the breaking of the wedge adjusting bolts in either the crank or cross head bearings. We have had about six of these break, but the trouble has each time been promptly located, and quickly repaired without further damage resulting.

OPERATING FIGURES

	Engine hours	Kw.-hours	Coal	Coal per kw.-hour	Average engine hour	Load factor*
Jan.	1140	304400	570199	1.873	36.8	0.445
Feb.	1060	278800	521190	1.869	37.8	0.438
March	1019	273600	531310	1.942	32.9	0.447
April	1032	256607	501145	1.954	34.4	0.414
May	902	248400	466935	1.879	29.1	0.459
June	872	257300	486804	1.892	29.0	0.492
July	913	275100	528452	1.920	29.5	0.502
August	1111	284900	556959	1.954	36.0	0.427
September	938	276800	533844	1.928	31.3	0.492
October	1102	302000	585037	1.939	35.5	0.457
November	1086	270700	534937	1.975	36.2	0.415
December	1228	327300	627469	1.917	39.6	0.430
Totals	12403	3355907	6444281		34.0	0.450 average

$$* \text{ Load Factor} = \frac{\text{Output}}{\text{Engine hours} \times \text{capacity of one engine}}$$

In addition to the coal, 260,292 lb. of coke were used in starting producers, of which amount 122,371 lb. were reclaimed, leaving the total net amount used 137,921 lb., equal in cost to 192,000 lb. of coal.

We have, therefore, for the total coal consumption 6,444,281 lb. + 192,000 = 6,636,281 lb.

$$\frac{6,636,281}{3,355,907} = 1.97 = \text{lb. of coal per kw-hr.}$$

Assuming 85 per cent efficiency for alternators at 45 per cent load we have

$$\frac{197}{133} \times 85 = 1.275 \text{ lb. of coal per b.h.p-hr.}$$

COST OF CURRENT

Cost of coal per kw-hr.	0.349	cts.
Cost of power house labor per kw-hr.	0.170	"
Cost of producer labor per kw-hr.	0.131	"
Oil for power house	0.065	"
Oil for producer	0.005	"
Waste and sundries, power house	0.012	"
Waste and sundries, producer house	0.003	"
Repair parts for engines	0.046	"
Repair parts for producers	0.007	"
Machine shop work, engines	0.016	"
Machine shop work, producers	0.007	"
Excelsior for producers	0.003	"
Water, both departments	0.071	"
Total cost of current at switch board per kw.-hr.	0.885	"

POWER CONSUMED BY AUXILIARIES

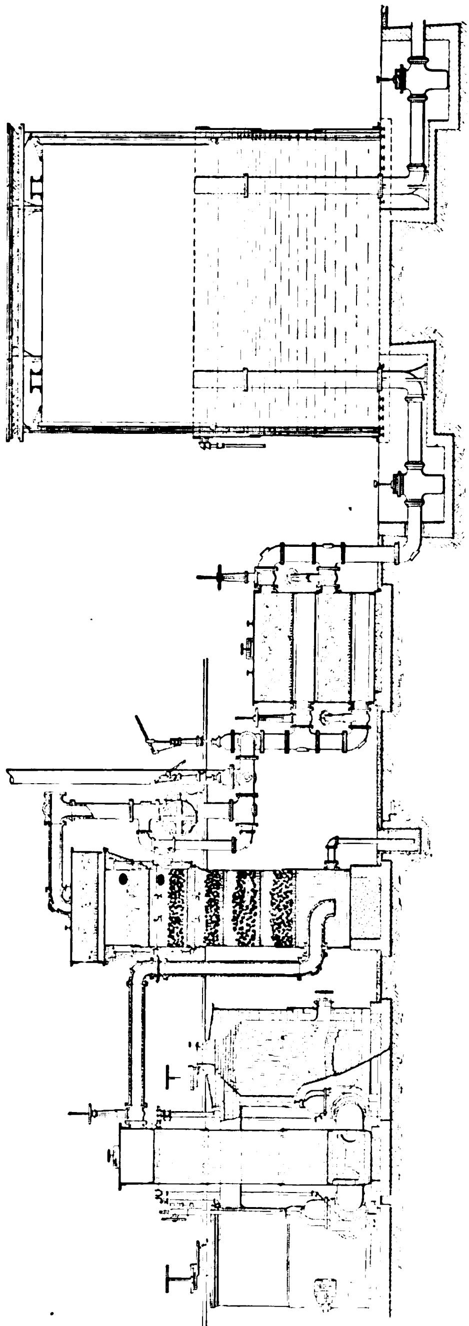
Cooling water pump, kilowatts per kw-hr	0.0095
Station lighting " " "	0.0116
Motor driven exciter " " "	0.0688
Total kilowatts per kw-hr.	0.0909

The items of interest, depreciation, taxes, etc., are not included, for the reason that they would be quite unfair to the plant, on account of the fact that it was designed for three 810-h.p. units, while only two have been installed.

Buildings, producers, gas holders, piping, etc., are all installed complete for the full ultimate capacity. Therefore a relatively small additional expenditure for one engine generator and foundation would increase the capacity of the plant by 50 per cent, while the foregoing items of interest, depreciation, etc. would be increased but 18 per cent per unit of capacity installed.

PRODUCER OPERATION

In starting a producer the generators are charged to a depth of five feet with 72-hour coke, requiring about 6000 lb. to each generator, or a total of 12,000 lb. The exhauster is then started, and the coke ignited. The gas made during the first 40 minutes is too inferior to be of any use in the engine, and it is therefore



Gas generating system

blown out through the purge stack and wasted, instead of being admitted to the holder. As the coke in the generators burns and becomes hot, coal is charged at the top in small quantities and at frequent intervals. If coal is charged too rapidly, particularly in the early stages of the fire, it tends to coke, with the result that the draught will be unequally distributed over the fuel bed, finding its way down through holes and localizing the heat to such an extent that the excessive temperature causes clinker to form, thus reducing the capacity of the generator and shortening by several days the time that the set can be run without shutting down for cleaning. When the fuel bed has attained a sufficiently high temperature, the purge stack is closed, and the gas is admitted to the holder. Steam is introduced at the top of the charging doors and, together with the air, is drawn in by the exhauster, passing down through the generator, forming a mixed gas. The carbon of the incandescent fuel combines with the oxygen in the air and steam, forming carbonic oxide gas and free hydrogen, the principal valuable constituents of producer gas.

At intervals of 20 to 30 minutes, up and down steam runs are made in the generators in the following manner: The by-pass around the exhauster is opened, the charging doors of the generators closed, and steam is admitted beneath the grate bars of one generator, the gate valve of which is closed, for about thirty seconds. This steam passes up through the generator, moistens the ash, breaks up the fuel bed and cools the fuel at the point where clinker is forming, and which is not reached by the top steam before decomposition takes place. This steam leaves the generator through a connection at the top, passing over into the top of the second generator, down through the fuel bed and out through the other apparatus to the holder as a fixed gas. The direction of the steam is reversed on the next run, so that the generators are alternately treated in the same manner.

The hot gas leaves the generators at a temperature of about 1200 degrees cent. and passes out through a brick-lined nozzle and water-cooled gate valve into the lower compartment of the vertical economizer, which is also brick-lined. A large part of the sensible heat of the gas is given off and goes to make steam which is used in the generators and for running the exhauster. From the top of the economizer the gas passes, at a reduced temperature, to the bottom of the wet scrubber where it is water sealed, and passing up through the wet scrubber, it works its way through several layers of coke over which water is sprayed

from above. During its passage through the coke and water most of the dust and lampblack in the gas is removed, and its temperature is reduced to that of the atmosphere. In the top of the wet scrubber a thick layer of excelsior removes part of the moisture and most of the remaining lampblack. From the wet scrubber the gas goes through the exhauster, then to the dry scrubber, where two more layers of excelsior thoroughly dry it, thence it passes to the holder, a clean, dry, cool gas.

It is very important that the gas should be reduced to atmospheric temperature in the wet scrubber by the use of a sufficient amount of cool water. About four to six gallons per horse power-hour is required, depending upon the temperature of the water and that of the atmosphere. If the gas is allowed to leave the wet scrubber hot, a large amount of water is entrained in the gas and carried in suspension over to the engines. The moisture in the gas is converted into steam by the heat of combustion in the engine, and the latent heat of the steam is absorbed from the burning gas, causing a total loss of this amount of heat to the engine, since the products of combustion are exhausted at a temperature far above that of condensation.

The use of a large holder, such as the one installed in this plant (60,000 cu. ft.) is of great value in operation. It takes up the variations in load and allows the producer to be operated at an even rate; also, if the gas varies in quality over short intervals, which is unavoidable, the gases above and below the mean value are thoroughly mixed and a gas of uniform quality is supplied to the engines.

A strip of metal on one of the guides of the holder, and insulated from it, is divided into ten parts, each representing about two feet lift of the holder. Each section is connected to one of ten lamps arranged vertically on the charging floor of the producer house. A roller on the lift of the holder makes contact with these strips, and lights a lamp in the producer house corresponding to the height of the lift. By means of this tell-tale the output of the producer is regulated. If the holder begins to fall, due to a continued heavy demand by the engines, the speed of the exhauster is increased, and the charging of coal is varied accordingly.

It may be of interest to describe here a rather serious difficulty which was encountered in this plant, and the way in which it was remedied.

A short time after the plant was put into operation, it was

found that some of the tubes of the economizers were leaking. The tubes were rolled and the leaks stopped, but in a short time they were found to be leaking again. They were again rolled, but continued to leak, and when finally too thin to be any longer rolled they were taken out and replaced with new tubes. The old tubes when taken out were cut into sections and split open, and it was found that they were badly pitted throughout their entire length, although the pitting was worse at the upper end; weighing the tubes disclosed the fact that they had lost nearly 25 per cent of their original weight. After much surmising, the cause of the pitting of these tubes is believed to be as follows:

In the usual design of plants of this kind, with two or more sets of apparatus, the various sets are absolutely independent of each other as far as the wet scrubbers, and as the gas is water-sealed in the wet scrubbers it is impossible for gas from one set to pass over into another. In this plant, however, in order to increase the flexibility of operation, the two economizers were connected together at the top by a horizontal header, and each one was cut off from the header by a gate valve. These gate valves coming in contact with gas at fairly high temperature expand and contract, and cannot be kept perfectly tight during steam runs. When the generators were under pressure, leakage of these valves permitted hot gas to pass from the economizer in operation to the one shut down, and after passing down through this economizer to escape through the open generators. It was found that the economizer not in use sweated profusely on account of the difference in temperature of the room and the water in the economizer, keeping the tubes continually wet. This moisture, combining with the hot gas leaking through the apparatus, undoubtedly formed a strong acid and attacked the tubes. Since arriving at this conclusion, each time a producer is shut down the gates of the valves are thoroughly cleaned, the tubes are cleaned with a wire brush, the tube ends and tube sheet are painted with one coat of graphite paint, and the manholes at top and bottom of the economizers are left open, so that a circulation of air prevents sweating. Since adopting these measures, there have been no more leaky tubes, and it is believed that the trouble has been effectually remedied.

At another time an annoying occurrence was the development of numerous hot spots on the shells of the generators; these hot spots were caused by defects in the linings. The brick of the

linings were laid with fire clay mortar joints, and the space between brick and shell was grouted with fire clay grout. The jarring occasioned by the heavy barring necessary to remove clinker, broke the bond of the joints and the grout behind the brick becoming pulverized, sifted out when the cleaning doors were open. To correct this trouble holes were tapped in the shell, and fire clay grout forced in at various places under about twenty pounds pressure. As the brick of the linings had thoroughly settled when this was done, no further recurrence of the trouble has been experienced. Had the brick been dipped in fire clay grout and laid brick to brick, and the space between the brick and shell been rammed with a mixture of fire clay grout and shredded asbestos, as is the practice with other gas generating apparatus, the trouble would probably not have occurred.

It is found to be an advantage after cleaning a generator to wash the surface of the brick exposed to the fuel with fire clay grout, as the grout tends to form a cleavage plane between clinker and brick and greatly facilitates its removal. When cleaning the generators, it is not desirable to remove all the clinker, for in doing so a part of the brick would be chipped off each time, and greatly reduce the life of the lining. About one or two inches of clinker adhering to the brick is allowed to remain, and this coating affords great protection to the surface of the lining.

Theory of Producer Gas Manufacture and Combustion

The chemical reactions that take place in the producer generators are practically as follows:

Air passing down over the green coal as it becomes heated by the incandescent coke in the generator, supplies oxygen for combustion of the carbon, and the intense heat produced drives off first the hydrocarbons, which are extremely volatile, in the form of vapor which when condensed becomes tar. This tarry vapor is drawn down through the hot fuel, and most of it burned to lampblack, which is later removed by the wet scrubbers, and the tar, which is most objectionable, is disposed of in a very simple and satisfactory manner. The remaining hydrocarbons are retained as fixed gases in the form of marsh gas or methane, CH_4 and olefiant gas, C_2H_4. These gases are both high in heat value and are extremely valuable, but are obtainable in very small quantities.

The fixed carbon of the coal combines with oxygen from the air or steam admitted, and forms carbonic oxide, CO, and car-

bonic acid gas. The former, considering the quality in which it is obtainable, is a most desirable gas; the latter contains no heat and is of no value whatever.

There are two ways in which carbonic oxide gas may be formed. When carbon is burned in oxygen present in insufficient quantity to afford complete combustion, a permanent gas is formed which passes out of the apparatus without further reaction. Since this is a simple and direct process, it would seem most natural and probable that the carbonic oxide is formed in this way. As a matter of fact, however, it has been pretty well established that the principal part if not all of the carbon monoxide gas is formed by a double reaction in the following manner: The air and steam supplied to the producer affords ample oxygen for complete combustion of the carbon in the coal at or near the surface of the fuel. As the complete combustion of carbon gives off heat at the rate of 14,647 B.t.u. per pound, the heat liberated raises the carbonic acid gas (CO_2) formed, to an intensely high temperature, and the hot gas passing down through the already incandescent fuel raises its temperature still higher, driving off carbon vapor, with each volume of which, one volume of carbonic acid gas combines to form two volumes of carbon monoxide. The combination absorbs the same amount of heat that would be given off if an equal weight of carbon monoxide were burned to form carbonic acid gas, *viz.*, 4,383 B.t.u. per pound. Since the molecular weight of carbon is 12 and that of oxygen 16, the product of combustion of one pound of carbon is $3\frac{2}{3}$ lb. of CO_2. In the second reaction, the $3\frac{2}{3}$ lb. of CO_2 combines with one pound of carbon, making $4\frac{2}{3}$ lb. of carbon monoxide (CO) of which 2 lb. consists of carbon and $2\frac{2}{3}$ lb. of oxygen. From the pound of carbon burned to form $3\frac{2}{3}$ lb. of CO_2 there was liberated and given to the producer 14,647 B.t.u., and in the reduction of $3\frac{2}{3}$ lb. of CO_2 to $4\frac{2}{3}$ lb. of CO an amount of heat equal to $2\frac{1}{3} \times 4383 = 10{,}227$ B.t.u. per each pound of carbon burned was absorbed from the producer, leaving a net gain to the producer of 4,420 B.t.u. per pound of carbon converted into carbon oxide. This is exactly the same as if a pound of carbon was burned directly to carbon monoxide.

If there was air alone admitted to the producer it can be readily seen that there would be a continual gain in heat to the generator with each pound of coal fired, and while high heat is conducive to a large production of carbon monoxide gas, and is desirable, an excessive heat will fuse the impurities of the coal and form clinker, closing the gas passages through the producer,

increasing the vacuum for a given output, and reducing its capacity to such an extent that it becomes necessary to shut it down and remove the clinker. While the production of a certain amount of clinker is unavoidable, the cleaning of a producer entails loss of fuel and expense of labor, and should be postponed as long as possible.

It therefore becomes necessary to control the temperature of the fire, and this constitutes a fine point in producer operation, for only experience can guide the operator, and for the best results good judgment is absolutely necessary.

To cool the fire, steam is admitted at the charging doors together with the air, in an amount depending upon load conditions. First of all, the temperature of the fire must be kept below that which would cause rapid fusing of the impurities. If the design of the engine is such that it will utilize a gas rich in hydrogen, without preignition, the steam may be increased to a point that will reduce the production of carbon monoxide, and increase the carbonic acid, while the loss in heat by the production of carbonic acid gas will be far more than compensated for by the high heat value of the hydrogen. The amount of steam cannot be increased indefinitely even if the engines would permit it, for the action of an excess of steam on the fire will cool the fire to such a degree that instead of being decomposed, it will pass through the generator in the form of live steam which is condensed in the holder and carried to the engine in the form of entrained moisture, the effect of which has already been explained. In general, we may say that the amount of steam to be used depends upon the rate of combustion, that is, it must be in proportion to the load, and the proportion depends upon the amount of hydrogen that the engine utilizes without preignition.

The effect of steam upon the fire is as follows: Steam entering at the charging doors and coming in contact with the hot fuel is disassociated into its constituent parts, *viz.*, oxygen and hydrogen. The action of the oxygen from the steam is identical with that of the oxygen in the air, and by combination with the carbon produces heat. Since hydrogen burning in oxygen to form water liberates heat in the amount of 62,032 B.t.u. per pound, conversely, when hydrogen is disassociated from oxygen, an absorption of heat in the same amount takes place. However, as the hydrogen and oxygen are introduced into the generator in the form of steam and as one pound of hydrogen combines with 8 pounds of oxygen to form 9 pounds of steam the latent heat of which from 70 degrees is 1,064 B.t.u. per pound, the net

heat absorbed from the producer is $62,032 - 9 \times 1064 = 52,456$ B.t.u. per each pound of hydrogen liberated,—hence the cooling action of steam.

To demonstrate this effect by figures, the molecular weight of carbon is 12, that of oxygen 16, and that of hydrogen 1. Six pounds of carbon, therefore, will combine with eight pounds of oxygen to form 14 pounds of carbon monoxide, from which the heat evolved is $6 \times 4420 = 26,520$ B.t.u., and one pound of hydrogen will be liberated, absorbing 52,456 B.t.u. The loss of heat, therefore, to the generator will be $52,456 - 26,520 = 25,936$ B.t.u. for each 9 pounds, or $\frac{25,936}{9} = 2,882$ B.t.u. per pound of steam supplied.

Hydrogen gas is very valuable within the limits that permit its use, and it is inexpensive to manufacture. The amount of water required is negligible, and the heat required to convert the water into steam is taken from the gas after leaving the generator, and if not utilized in the economizer would be wasted in the scrubber. Its heat of combustion is very high, and although this heat is borrowed from the generator, it is heat that is liberated in the production of carbon monoxide, and like the heat of the gas, if not absorbed by the hydrogen it would finally be wasted by radiation and in heating the water of the scrubber.

In order that the operator may efficiently perform the duties of his position it is necessary that he should have a clear idea as to the nature and extent of the various losses that occur from the coal pile to the switchboard. For this purpose, actual figures, though not necessarily more than approximately correct, afford the best demonstration.

Taking for example the coal which has been used throughout the operation of this plant, a high grade of Pocahontas coal, we obtain from the United States Geological Survey the following analysis:

Proximate analysis		Final analysis	
	Per cent		Per cent
Moisture	1.90	Carbon	85.87
Volatile carbon	18.08	Hydrogen	4.65
Fixed carbon	77.03	Oxygen	4.64
Sulphur	0.67	Nitrogen	1.19
Phosphorus	0.008	Sulphur	0.67
Ash	2.312	Phosphorus	0.008
		Ash	2.972
Total	100.0		100.0

Heat value, calculated, 15,039 B.t.u.
Heat value, by calorimeter, 15,344 B.t.u.
This calculated value is checked approximately as follows:

Carbon	85.87×14647 =	12577	B.t.u.
Hydrogen	4.65×62032 =	2884	"
Total		15461	"
Deducting latent heat of evap.	$0.0465 \times 9 \times 1064$ =	445	"
Net heat value		15016	"

At the end of a run on one producer covering a period of 19 days during which time 293,000 lb. of coal was converted, the residual removed in cleaning the generators was carefully weighed, and found to be as follows:

Clinker from generators	13328 lb.
Ashes and lampblack from generators	3221 "
Ashes and lampblack from economizers	168 "
Total	16717 "

and in addition 5,351 lb. of good coke, suitable for use again. The 16,717 lb. of waste material is 5.7 per cent of the total coal converted, and while the analysis of the coal shows only about 3 per cent of sulphur, phosphorus and ash, the balance of weight, *viz.*, 2.7 per cent is no doubt supplied by oxygen with which some of these impurities combine at the high temperature of fusion.

From this coal we assume the gas to have the following analysis by volume, *viz.*

Carbon monoxide CO	20.3
Hydrogen H	11.6
Methane CH_4	1.2
Olefiant Gas C_2H_4	0.3
Carbonic acid CO_2	8.2
Nitrogen N	58.4
Total	100.0

While this is by no means a high grade gas from the above coal, the analysis is assumed purely for the sake of explanation, although it is believed to be a fair average of the gas produced in the plant.

From the above analysis of gas is computed the following table:

TABLE OF GAS AND AIR FOR COMPLETE COMBUSTION

Symbol gas constituent	Per cent by vol.	Weight in one cu. ft. of gas	Per cent by weight	B.t.u. per cu. ft.	B.t.u. one cu. ft. gas	Air in pounds for complete combustion			Products of combustion		Dilutant Nitrogen	Carbon and hydrogen	
						Oxygen	Air	*Nitrogen	Pounds CO_2	Pounds H_2O		C pounds	H pounds
CO	20.3	0.015868	21.67	243	69	0.009068	0.039430	0.030362	0.024936	-	—	0.006800	—
H	11.6	0.000648	0.89	347	40	0.005184	0.022540	0.017356	—	0.005832	—	—	0.000648
CH_4	1.2	0.000536	0.73	1072	13	0.001072	0.004661	0.003589	0.001474	—	—	0.000402	—
	—	—	—	—	—	0.001072	0.004661	0.003589	—	0.001206	—	—	0.000134
C_2H_4	0.3	0.000234	0.32	1711	5	0.000534	0.002321	0.001787	0.000734	—	—	0.000201	—
						0.000264	0.001150	0.000886	—	0.000297	—	—	0.000033
CO_2	8.2	0.010122	13.82	—	—	—	—	—	—	—	—	0.002760	—
N	58.4	0.045815	62.57	—	—	—	—	—	—	—	0.045815	—	—
	—	—	—	—	—	—	—	0.057569	—	—	0.057569	—	—
Total......	100.0	0.073223	100.0	—	127	0.017194	0.074763	—	0.027144	0.007335	0.103384	0.010163	0.000815

Air required per cu. ft. of gas for perfect mixture 0.9259 cu. ft.
Air required per pound of gas for perfect mixture 1.0213 pounds.
B.t.u. lost by latent heat of evaporation $0.007335 \times 1064 = 7.80$ B.t.u. per cu. ft. of gas.
Net heat value of gas $127.0 - 7.80 = 119.2$ B.t.u.

Assuming that 76,118 cu. ft. of the above gas will be required by one 810 b.h.p. engine operating for one hour at full load, we then have:

Constituents of gas	Weight in 1 cu. ft.		Weight in 72710 cu. ft.		Heat units	
	C.	H.	C.	H.	Lost in producer	Retained in gas
CO	0.006788		493.55		2,181,491	5,047,535
H		0.000648		47.12		2,922,947
CH_4	0.000402		29.22			427,985
		0.000134		9.74		604,192
C_2H_4	0.000202		14.68			215,018
		0.000032		2.32		143,914
CO_2	0.002760		200.67		2,939,213	
N	inert					
Total			738.12	59.18	5,120,704	9,361,591

Dividing the amount of carbon by the percentage contained in the coal we get $\frac{738.12}{85.87} = 859$ lb. of coal required for 72,710 cu. ft. gas.

In this coal there appears 4.65 per cent of hydrogen of which 4.44 per cent is apparently in the form of hydrocarbons, the hydrogen of which undergoes no reaction in the producer. The balance, 0.21 per cent, is in the form of moisture, and will be classed with hydrogen obtained from steam.

Therefore we have $859 \times 0.0444 = 38.14$ lb. of hydrogen in hydrocarbons and $59.18 - 38.14 = 21.04$ lb. of hydrogen derived from steam, the heat value of which $21.04 \times 62.032 = 1,305,153$ B.t.u. is absorbed from the producer and should be deducted from the total amount under head of "heat lost." We have, therefore, for the net results,

Heat lost in producer, 5,120,704 − 1,305,153 =	3,815,551	B.t.u.
Heat retained in gas	9,361,591	"
Total heat of combustion of 859 lb. of coal	13,177,142	"

showing a loss of 28.9 per cent in the producer.

It would seem that the analysis of gas assumed is unfair to the producer, for the relatively small amount of hydrogen (less than 0.32 per cent by weight) introduced into the producer in the form of steam, would indicate that the producer was being operated at high temperature, and therefore a large amount of

carbonic monoxide would be formed and a correspondingly smaller amount of carbonic acid than the quantities given in the analysis, resulting in a gas of higher heat value and a higher degree of efficiency for the producer.

From 859 lb. of coal consumed, 810 b.h.p. for one hour were produced, from which the coal consumption is $\frac{859}{810} = 1.05$ lb. of coal per b.h.p-hr. This is about in line with the 1.275 lb. of coal per b.h.p-hr. at 45 per cent load factor, which was the average consumption of the plant under discussion for the past year.

From the table we find that one cu. ft. of gas requires 0.926 cu. ft. of air for complete combustion, and therefore 72,710 cu. ft. of gas will require $72{,}710 \times 926 = 67{,}402$ cu. ft. of air, making a total mixture of $72{,}710 + 67{,}402 = 140{,}112$ cu. ft.

The displacement of the piston in one power stroke is 9,574.464 cu. in. = 5.54 cu. ft., and as there are 28,800 power strokes per hour, the total displacement per hour is $28{,}800 \times 5.54 = 159{,}952$ cu. ft. If the full load capacity of the engine is 87 per cent of its ultimate capacity, then $159{,}952 \times 0.87 = 139{,}158$ cu. ft. is the full load displacement per hour, and the suction efficiency of the engine would be $\frac{140{,}112}{139{,}158}$ or a trifle over 100 per cent. As this is not possible it is evident, if the figures are correct, that, the assumption of 72,710 cu. ft. of gas at 119.2 B.t.u. per cu. ft. is a little more than required to develop 810 b.h.p. hr. at the full load rating of the engine, provided the engine is properly rated. However, as the error is small, we will continue in the original assumption as to quantity and value of gas and derive from the above figures the following approximate heat balance:

Heat lost in producer and auxiliaries	3,815,551	B.t.u.	28.9	per cent
Heat lost in engine friction at 84 per cent mechanical efficiency $\frac{1980000 \times 154}{772}$	394,977	"	2.9	"
67437 lb. of water raised 40 degrees, specific heat 1.013 $67437 \times 40 \times 1.013 =$	2,734,000	"	20.8	"
Latent heat of evaporation 532.62 lb. steam at 1064 B.t.u. per pound	566,707	"	4.3	"
Lost in radiation and exhaust	3,588,446	"	27.3	"
Total losses	11,099,681	"	84.2	"
Heat effective in engine $\frac{1980000 \times 810}{772}$	2,077,461	"	15.8	"
Total heat of combustion	13,177,142	"	100.0	"

Since the specific heat of the products of combustion is not known for temperatures as high as exist in the exhaust, it is impossible to compute the heat lost in this direction, and therefore the heat lost by radiation and by exhaust can only be arrived at by elimination.

The specific heat of the products of combustion containing 15 per cent CO_2 is given as 0.323 for 100 degrees fahr., and it is known that the specific heat of all gases increases considerably with increased temperatures. If the amount of heat, *viz.*, 3,588,446 B.t.u. as derived by our heat balance is correct and the temperature of exhaust 800 degrees above atmospheric, which is approximately true, there being $72710 \times 0.148{,}123 =$ 10,761 lb. of gas delivered from the exhaust, the specific heat (neglecting loss by radiation of engine) would have to be $\frac{3588446}{10761 \times 800} = 0.413$, as compared to water, which would seem to be a reasonable value.

In Conclusion. That the gas engine has a wide field of usefulness is no longer disputed, but whether it is adapted to conditions of operation such as are met in the plant described is very questionable, unless it be in connection with a storage battery. Other factors however than the conditions of load, as in this case, often enter into the question, and bring influence to bear upon the adoption of a system seemingly unsuitable for the conditions in hand.

The economy of the gas engine has long been conceded, and its reliability at the present time has been proved without a shadow of doubt. An engine in the Edgar Thompson Works of the U. S. Steel Corporation has operated continuously night and day for six months with the total loss of only three hours time; and other records that would do credit to any class of prime mover are to be had in numbers.

When a source of power at low price but uncertain continuity is available, a gas engine and producer will prove a most perfect relay, provided the character of service will warrant the cost of reserve power.

With the holder full of gas and the exhauster of the producer stopped, the fires in the generators will smoulder with almost inappreciable stand-by loss. The engine may be started and put under load in less than two minutes, and the producer can be brought up to working condition before the gas in the holder is exhausted.

Again, when natural or blast furnace gas is available, or when location renders the cost of fuel high, the gas engine has no competitor. Fuel can be utilized in the producer that is absolutely unfit to be burned under a boiler, but even where conditions are more favorable to steam, the gas engine makes a most respectable showing.

NOTE

The following paper is to be read at the 246th meeting of the American Institute of Electrical Engineers in **Charlotte, N.C., March 30-April 1, 1910.** This paper is to be presented under the auspices of the High Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, Chairman, High-Tension Transmission Committee, 60 Wall St., New York,** so that they will be received not later than March 25, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

A paper to be presented at the Charlotte meeting of the American Institute of Electrical Engineers, March 30-April 1, 1910.

(*Subject to final revision for the Transactions.*)

PARALLEL OPERATION OF HYDROELECTRIC PLANTS

BY W. S. LEE

It is the purpose of this paper to sum up in a general way some of the advantages to be gained by operating a sytem of hydroelectric plants connected in parallel so as to exchange power from one plant or territory to another. The disadvantages of this system, which are almost all transmission operating conditions, have been purposely omitted, in the hope that some member may at a future meeting treat this phase of the subject, giving a solution of the problems involved. The deductions, although drawn from conditions existing on the southern Appalachian slopes, will in most cases apply to other localities.

It seems best to first consider some of the topographical features of this locality. The Appalachian mountains, in which many large streams have their sources, run in a southwesterly direction, paralleling the Atlantic coast. These mountains are, on an average, from 1500 to 2000 feet above the sea level. This means that all water from their water sheds must run over falls or rapids dropping a total vertical distance corresponding to this height. In the higher altitudes there are numerous waterfalls with an abrupt drop of many feet, but as lower levels are reached the falls consist mostly of rapids, some grouped so as to present considerable fall in a short distance, and in other places a longer and more gradual slope.

Several well-defined ridges cross the various streams running parallel to the Atlantic slope, on which each river has a decided fall. These ridges extend across two or more states and several streams. These points on the streams present the largest and most economical sites for hydroelectric developments. Near

these falls, or between them, are others of a gentler slope which are much more costly to develop.

Each stream has available a certain amount of water power and the problem is to build and operate plants on the same and on different streams, interconnecting them with transmission lines, so that the greatest amount of power can be delivered from all the streams.

For convenience, we will consider the advantages to be gained by parallel operation under the following heads:

More than one plant located on the same stream.

Plants located on different streams.

Effect of low water on a system of plants.

Effect of high water on a system of plants.

Storage.

Break-down capacity.

Auxiliary plants.

Variation of load.

Constructing and operating advantages.

More than One Plant Located on the Same Stream. Rainfall and floods are features that should be carefully considered in connection with hydroelectric plants especially when operated in parallel. To illustrate this point some tabulated data are given regarding rainfall from the year 1900 to 1909 at the stations located at Morganton, N. C., Statesville, N. C., Charlotte, N. C. and Camden, S. C., all forming part of the drainage area of the Catawba river.

It will be seen by referring to this table that in several instances one point may have an excess of rainfall and another have a deficiency, or vice versa.

After the plants are built comes the consideration of their operation during various stages of water. The two stages which interfere with operation are extreme low water and extreme high water. While low water generally extends over the whole country it is very unusual that there are not some places where the streams furnish more water than others, due to variation in rainfall or to climatic conditions. These places may not necessarily be in the same section each year, and the areas of increased or decreased rainfall may shift and vary from year to year.

Low water means a curtailment of power, and it is often found that even with a line of plants located on the same stream the water conditions are different at different plants. There may be

AVERAGE RAINFALL

Year	MORGANTOWN, N. C.				STATESVILLE, N. C.*				CHARLOTTE, N. C.				CAMDEN, S. C.			
	Av. precip. for prev. years	Annual precipit.	Excess	Defic.	Av. precip. for prev. years	Annual precipit.	Excess	Defic.	Av. precip. for prev. years	Annual precipit.	Excess	Defic.	Av. precip. for prev. years	Annual precipit.	Excess	Defic.
1900	*11* 47.93	46.68	—	1.25	*6* 53.01	No. Record	—	—	*21* 49.64	46.34	—	3.30	*10* 47.15	51.79	4.64	—
1901	*12* 47.83	63.19	15.36	—	*6* 53.01	62.84	9.83	—	*22* 49.49	62.82	13.33	—	*11* 47.57	58.64	11.07	—
1902	*13* 49.01	44.77	—	4.24	*7* 54.41	48.35	—	6.06	*23* 50.07	45.32	—	4.75	*12* 48.49	45.17	—	3.32
1903	*14* 48.70	52.04	3.34	—	*8* 53.66	53.64	—	0.02	*24* 49.87	39.48	—	10.39	*13* 48.24	55.06	6.82	—
1904	*15* 48.93	42.31	—	6.62	*9* 53.65	36.70	—	16.95	*25* 49.45	41.93	—	7.52	*14* 48.72	37.90	—	10.82
1905	*16* 48.51	57.04	8.53	—	*10* 51.96	49.91	—	2.05	*26* 49.17	42.44	—	6.73	*15* 48.00	42.41	—	5.59
1096	*17* 49.02	57.86	8.84	—	*11* 51.77	50.82	—	0.95	*27* 48.92	47.30	—	1.62	*16* 47.65	51.17	3.52	—
1907	*18* 49.51	47.94	—	1.57	*12* 51.69	39.46	—	12.23	*28* 48.86	39.98	—	8.88	*17* 47.86	45.61	—	2.25
1908	*19* 49.42	66.44	17.02	—	*13* 50.75	Partial Record	—	—	*29* 48.55	54.40	5.85	—	*18* 47.74	51.15*	4.41	—
1909	*20* 50.27	No Record	—	—	—	—	—	—	*30* 48.75	No Record	—	—	*19* 47.97	No Record	—	—

* Mean of 2 observations.

NOTE.—Records of missing months have been interpolated by using corresponding records of adjacent rainfall stations. Italic figures in columns for average precipitation denote the number of previous years.

local rains that benefit one plant one day and do not benefit plants at some distance for two or three days thereafter.

In case of operating under flood conditions the reverse is true, namely; a flood may affect a plant on the upper part of the river and not affect a plant lower down for several days. In the meantime the water has become normal at the upper plant and no longer interferes with its power output or the proper speed of the wheels.

On a system where several plants are located on the same stream, the head operator has many problems which can be solved to the company's advantage by passing water from one reservoir to another, so as to produce the greatest kilowatt-hour output from the combined plants.

Plants Located on Different Streams. It will be readily observed that many of the same conditions and advantages that apply to several plants located on the same stream, apply to plants located on different streams. There are, however, some features in connection with low water and floods which should be considered. The question of low water can be handled much more advantageously when plants are located on different streams as it is rarely the case that areas of abnormal rainfall extend over different valleys and different parts of them to the same extent. The rainfall may vary a great deal even in the same valley, but this variation is always more pronounced in different valleys. Just as the effects of low water are minimized by having plants on different streams, so are the effects of high water. The floods that interfere with the operation of plants are the large ones, and it is a very rare occurrence to have a large flood on two different streams at the same time.

Effect of Low Water on a System of Plants. The low-water flow of any stream or streams in connection with a hydroelectric system operated in parallel, determines the value of the system. In the operation of plants located many miles apart not only can advantage be taken of variation of rainfall in different parts of the various drainage areas, but it is found possible to regulate the flow of water from plant to plant on the streams so as to produce the greatest power output.

In operating such a system of plants on the load in this territory, we are often enabled to lower the ponds or storage capacity towards the end of the week, refilling them on Sundays.

If an operating man has only one plant he dares not take any chances by lowering the water in the pond to too great an extent.

the result being that he does not get the amount of power from the plant that he would if it operated in parallel with other plants.

As to just what this increased value of power output is cannot be determined except for fixed systems, but for any system in which there are as many as three plants, well located, it is safe to say that the low-water output can be increased at least 15 per cent.

Effect of High Water on a System of Plants. In the case of low-head plants, high water affects them very materially owing to the fact that the decrease from normal head is a large proportion of total head. On the other hand, the higher head plants are not affected so much. It very rarely occurs that all plants in a system are of the same head; consequently, the system would have an operating advantage in time of high water due to this reason. Also, in considering the flood action on a system of plants on the same stream, we must investigate the velocity of such a flood. There may be heavy rains in one part of the valley causing an excessive local flood that will not affect a plant located thirty miles or more below, and the upper plant can be put back into commission before the flood will affect the plant lower down, and so on.

Storage. It is evidently advantageous to have a chain or system of plants in connection with the storage of water. When the plants are connected together in parallel it matters not what size reservoir each particular plant may have, as all the water can be made available by the operator as if it were in one large reservoir. This, of course, will make it necessary for the operator to draw continuously on plants that have small reservoirs, using the plants with large reservoirs in cases of emergency or heavy peak loads.

Excess or Peak Load Capacity. In every plant it is necessary to have an overload or peak load installation, as no power service has a steady load at all times. In the construction of hydroelectric plants it is always found advisable to install some additional equipment for this purpose. The percentage of this excess capacity is necessarily greater in an isolated plant than it would be where several plants are connected together in parallel. In cases where several plants are operated in parallel the excess capacity can often times be installed in plants nearer the load, or in a more desirable place for operation, than would be possible if each plant had to carry its proportionate amount of reserve capacity.

Breakdown Capacity. It is well known to all operators that interruptions to some plant are liable to occur from time to time, due to breakdown or some defect which may develop. It can readily be seen that with a chain of plants an interruption at one plant would not be serious, as other plants on the system could be called on for overload or excess load during such an interruption. It often happens that some breakdown in one plant could be repaired much quicker if the whole power house could be shut down.

Auxiliary Plants. Due to the extreme variation of high and low water, one of the problems in hydroelectric development is to be able to get as much power as possible from a variable stream. If a plant is based and built on extreme low water, there is from six to twelve months in the year, varying of course with the rainfall, a great amount of surplus power. It becomes very desirable to make installations that will take care of as much of this flowage as it is profitable to sell. These variations are so erratic that they cannot be even approximately determined, and it is therefore necessary to install some auxiliary plants. When plants are operated singly it is generally necessary to place an auxiliary steam plant at the water power plant, and as water powers are generally in some out of the way place, the cost of construction and operation of the auxiliary is high. But where a system of plants is operated in parallel the problem of auxiliary plants is very much simplified. Plants may be located so as to take care of territories at the ends of transmission lines; or they may be in the midst of the largest power districts, thereby reducing the line loss; or they may be placed at a point where low freight rates on fuel prevail.

Variation of Load. The ideal load for any power system is one made up of a great number of different kinds of customers. The greater the territory over which any system operates, necessarily the greater the diversity of manufactures, and the nearer do we approach ideal conditions. The largest part of the load in this particular section consists of cotton mills, and although this is supposed to be a ten-hour constant load there is a variation on our different lines from week to week, due to the market demand for different classes of goods. To cite a particular case; a number of mills in one locality spinning coarse yarn may be shut down in the middle of the week, while the mills in another district, spinning fine yarns, may be running overtime, due to the demand for these particular goods; consequently, a system of

plants will have a much better load factor than would be possible with singly operated plants.

Constructing and Operating Advantages. Another great advantage to the construction engineer while building on a stream on which some other plant is operated above him, is the ability to regulate the flow of the river while putting in coffer dams or difficult parts of the foundation. This, of course, would only apply to a plant located below one in operation, but it can be used many times during course of construction.

The advantages of operating a large transmission system are many and easily understood by the practical operating man. The operating manager is able to handle the system from one point to much better advantage than if it had to be operated from different points. He has a better opportunity of training his operating forces, as the men can be promoted from one department to another as they become proficient and familiar with the system.

We next come to the question of cost of attendance for a system of plants. The load in this particular territory is such that it does not require all of the plants to be in operation more than twelve hours a day. This enables the company to so man the stations that twenty-four hour shifts are not necessary in all plants.

One Transmission System Where Possible

In the Piedmont section are many small growing towns scattered several miles apart and vying with each other in manufacturing. As there is a large territory to cover its calls for a high tension *distributing* rather than a high tension *transmission* company.

If parallel operation of generating plants is economical, desirable, and capable of better service to customers, why is not one transmission system best to serve a large territory? Let us consider the following problems in regard to the transmission system:

Ability to furnish better service.

Cost of transmission system.

Serving one or more generating companies.

Construction and operation.

Ability to Furnish Better Service. The matter of first consideration to the hydroelectrical engineer of any system, great or small, is reliability of service. If there are advantages in operating gen-

erating plants in parallel there must be still greater advantages in supplying customers from one general transmission system. The large transmission system presents many possibilities for belt lines and tie-in lines, which strengthen the service and which would not be possible on a small isolated system. Duplicate lines can be so laid out that while they are not built close together they eventually reach the same point. By this plan they reach and serve separate territories and come together at a fixed point, there furnishing duplicate service. In case of interruption to one line, power can often be furnished from another direction until necessary repairs can be made.

Cost of Transmission System. In the construction of a large distributing system the lines will probably cost more at first than those of the smaller system. As the country develops and the load increases, the relative cost will be reduced, so that the final cost will be less per kilowatt than for several small systems. There will be an increased cost, due to many switching and tie-in stations, but this, I believe, will be offset by being able to work the lines up to their full capacity. The larger systems will only add additional lines as the load increases to warrant their construction, while, on the other hand, it would be almost impossible to lay out the small system so as to use all the copper in the lines to best advantage.

Serving One or More Generating Companies. When a large transmission system is laid out to serve power consumers to the best advantage, it is an easy matter to tap the system and take on additional power from any new generating station.

The operation of a hydroelectric system resolves itself into three parts; generation, transmission and distribution. Any part is susceptible of being segregated so as to determine its pro rata cost or profit. This being the case, it will readily be seen that a large transmission system will furnish to the prospective builder of a generating plant a better market for the sale of his output than he would have if he determined to enter all three fields. It will make no difference to the distributing system whether the generating plants are owned by the same company or by different companies.

Constructing and Operating Advantages. Owing to the fact that most water power sites are in almost inaccessible places, the question of power for use during construction should be considered. If the plant is built with a view to operating in parallel with some other plant it is merely a question of building the

transmission lines at first and using power from the completed plants for constructing the new ones. This has been worked out in actual practice and is found very desirable.

Conclusion

The advantages enumerated above which are claimed for plants operating in parallel are in the ultimate, economic ones, and this paper does not seem complete without some reference to the general conditions surrounding the water power situation at the present time.

We have already referred to the benefits to be derived from the proper location of the various dams on a stream, but even at this early stage of the hydroelectric art we find it necessary to consider conditions already existing. In many places we find the power of water falls has been partially utilized in a manner which makes complete development of their power almost impossible without destroying existing developments. We also find in many places a little fall above and below sites for development, covering several miles of river front, which is difficult to include. The development is often made to include only the main fall on account of the difficulty of acquiring the riparian rights for the total fall. Again, other obstacles are often encountered, such as highways or railroads which interfere with complete development, and a partial development is made without removing these obstacles which could often be done to the satisfaction of everyone. This is a very poor policy and is equivalent to wasting that much of available power.

Furthermore, almost every undeveloped water power is in some remote place difficult of access. This makes it necessary to provide some means of transportation for machinery and materials during construction. This item of transportation is a large part of the cost of development, especially when the plant is a small one. For this reason, if for no other, each of these developments should be considered very carefully with the idea of developing as large a power as possible, even if it is necessary to spend some time in getting additional water and flowage rights.

And here let me advocate the passage of liberal condemnation laws, so that anyone actually desiring to develop a water power could do so without being blocked by minor or unimportant interests, for up to the present time it has been found that one of the most difficult matters in connection with hydroelectric development is the acquisition of land and riparian rights.

This item represents about 10 per cent of the cost of development. Several of the states have passed condemnation laws, and other states, which have no general law, often give special charters allowing condemnation. While there is a tendency on the part of many people to object to this policy, it should be continued.

It is a well established fact that the growth of the country around a development is very rapid, increasing the taxable values not only by the amount invested in the development but also by the investment in manufacturing interests which follow them.

I know of no business in which as much money has been invested as in hydroelectric developments that has made such a poor return on the investment. Seventy-five per cent of the reports made on proposed hydroelectric developments are jokes. Moreover, the local papers, when a development is proposed or started, are eager to magnify the amount of power, the cost of construction and the value of the investment. The result is that the entire country has been trained to believe in a general condition that does not exist. Promoters have taken advantage of this condition, and many plants have been built or started that have proved failures.

The investigation of a proposed hydroelectric development requires a great deal of work and study by trained and experienced men, as there are more varying features entering into consideration than in any other branch of engineering. Most reports are made hurriedly without proper investigation, hence disappointment follows. The engineers who make these reports are not wholly to blame, for they are seldom allowed the necessary time or facilities to make proper investigation on account of the cost involved.

The standard for determining the cost of power to-day is based upon the cost of power produced from coal. As the supply of coal is consumed the cost of power will necessarily increase and a new standard of cost will be established. Any tendency to block or interefere with the development of water power is necessarily forcing the consumption of coal and hastening the day when the price of power must increase according to the law of supply and demand. I fear that many of our conservation advocates who are endeavoring to prevent the destruction of our natural resources are really hastening it.

We are all aware that our Government, which should publish

carefully and accurately prepared reports, is contributing an influence which is not favorable to the early development of our water powers. Some laws have been passed, and still many more proposed, with apparently no other object than to stop further development. The public which has been taught that the investor is getting more than he should, endeavors to block development in every conceivable way. The result of these conditions is that the investor has been sorely disappointed and is ceasing to invest. In the meanwhile, a latent or dormant energy is running to waste, and we are consuming a limited coal supply which should be preserved.

The engineering profession should study these conditions carefully and exert every influence to place this matter before our Government and the public in its true color; thus only can we hope to utilize in the immediate future the vast resources of our streams with the greatest possible economy.

To my mind *true conservation* does not consist in postponing the utilization of power now going to waste, and which can never be regained, but rather in utilizing these resources at present that cannot be kept for use at a future time.

NOTE

The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **San Francisco, May 5-7, 1910**. This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

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Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, c/o Prof. Harris J. Ryan, Stanford University, Cal.**, so that they will be received not later than May 1, 1910.

A paper to be presented at the San Francisco meeting of the American Institute of Electrical Engineers, May 5, 1910.

(Subject to final revision for the Transactions.)

EMERGENCY GENERATING STATIONS FOR SERVICE IN CONNECTION WITH HYDROELECTRIC TRANSMISSION PLANTS UNDER PACIFIC COAST CONDITIONS

BY A. M. HUNT

No matter what care and skill are exercised in designing and constructing a hydroelectric plant, with accompanying high-tension transmission lines, absolute continuity of service is a thing which cannot be assured. This is more particularly true of our western plants as compared with those of the eastern section of the country, and is especially true in California. Practically all of our important hydroelectric plants are located on streams which find their way down the western slope of the Sierra Nevada range of mountains through deep canyons. The sides of the canyons are usually very steep, and furnish very poor foothold for ditch construction. The cost of driving tunnels is usually prohibitive, and in the majority of cases, box flumes, built of lumber, are used to carry the water.

Our winter season is one of rains and heavy precipitation, and it is not infrequent that flumes go out, due to water-soaked foundations, slight leaks undermining footings, breaks caused by falling rocks, or other causes. This means an interruption of power service. Interruptions may and do come from line troubles due to many causes.

Interruptions of service were more than occasional in the earlier days of transmission work on the coast, and even to-day with the better construction and design, and greater care and watchfulness in operation, they occur often enough to be matters for serious consideration.

The best means for avoiding the serious results from inter-

ruptions of service, is to reduce the period of time during which power is off the line. Any interruption of service is serious, but if a prospective power purchaser could be assured that his interruptions would be a minimum, and that when they did occur, they would be of very short duration, he would not be so apt to refuse to purchase power from the hydroelectric company on the score that the supply was not dependable. Such shortening of duration of interruption can best be accomplished by having at the receiving and distributing point an emergency generating station, maintained at all times in such a state of preparedness that it can be started and put on the line in the shortest possible time.

Under the conditions existing in California, it may become necessary to operate such a stand-by plant continuously for considerable periods, due to seasons of low water, and it is, therefore desirable that its economy should be good. In fact, I believe I may safely state that no stand-by plant has been installed on the coast which has not become an important operating factor of the system with which it is connected.

I propose to discuss the type of stations for this service, making comparison between a station having generators driven by gas engines, and one in which steam-driven turbo-generators are used. I shall try to establish the thesis *that the turbine station can be so designed as to be built at much less cost than the gas-engine station; that it can be kept in a state of preparedness where it can be put into service on the line as promptly as the gas engine station; that its stand-by charges will be less than for the gas-engine station; and that its economy, when called on for continuous operation, will be at least as good as that of the gas engine station.*

Premises Assumed. The station shall have a capacity for continuous operation of 25,000 kw. at 85 per cent power factor.

Crude petroleum will be the fuel used both for generating steam and for gas making.

The station to be located at a point where spur-track facilities are available, and where ample water supply can be had.

In making comparison of economies with station in continuous operation, it is assumed that the load factor will be 50 per cent.

General Outline of Gas Engine Station

The station will contain 12 units, each having a continuous load capacity of 2085 kw. at 85 per cent power-factor. The size of unit is small for a station having such a large capacity, but it is

extremely doubtful if any of the engine builders will agree to build and guarantee larger engines, especially for use with gas made from oil. The experience with the large gas engines in the Martin station of the Pacific Gas and Electric Company indicates that the safe limit was passed there.

The following quotations from recent letters received from one of the large gas-engine builders is also confirmatory:

From reports made by various members of our engineering department, who have noted the large continental engines in operation, we gather that while some very large cylinders are still operating in the single-acting type, the European, and particularly the German companies, who have built larger than 42 inch or 44 inch diameter, using cast iron as the material, have been compelled to replace practically all of their cylinders, leads us to believe that they should not be attempted at all in cast iron, and if steel is used with cast-iron bush, the cost per brake h.p. will be much larger than a smaller sized unit, without any gain in efficiency or lessening of operating expense.

If economy is the controlling factor, it would seem to us that a size such as our 37½ in. x 48 in. (3100 brake h.p.), which can be made safely, with cast-iron cylinders would be a better proposition than a larger engine with longer stroke and larger diameter of cylinders which it would be necessary, or desirable, at least, to make of cast steel. We can readily understand how large power houses want turbine units of very large capacity of 10,000 kw. or more, as the economy of the turbine unit increases perceptibly as the sizes grow larger, and these very large units can show economies which are difficult to reach with the smaller sizes, but with the gas engines, if there is any difference at all, the reverse is the more likely to be true, as cylinders of moderate size can be effectively cooled and used with water of ordinary temperatures, while with the very large cylinders, in order to keep certain spots from getting hot enough to ignite the gas, other parts of the cylinders have to be kept unnecessarily cold. The desirability of good parallel operation also tends to cause a choice of smaller cylinder diameters, as with very large engines the slow speed and great number of poles cause the generator builder's requirements for operation to be very close indeed, and the weight of the flywheels becomes prohibitive, both from the point of first cost and from the ability of the bearings to stand the load without heating.

The gas required per 24 hours will be 7,500,000 cubic feet, based on 650 B.t.u. per cubic foot, 50 per cent load factor, and assuming that by reason of the relatively small size of units, the engines will always be operated at approximately full load.

The gas-generating plant will consist of three oil gas sets, each capable of producing 2,500,000 feet of gas per day, with necessary condensers, scrubbers, and purifiers, and a holder capacity of 2,250,000 cu. ft. to equalize the daily load. It is assumed that the units will have twin tandem engines, and the

over-all size of foundation for one unit will be 70 ft. by 30 ft. Allowing for passages, the size of electric generating station will be 76 ft. by 400 ft. if engines are placed in one continuous line, or 152 ft. by 200 ft. if placed in two parallel lines. The station will have the usual compressed-air starting equipment.

General Outline of Turbo-generator Station

This station will be assumed to contain two turbine units, each having a continuous capacity of 12,500 kw. at 85 per cent power-factor. Each unit will have its condensing equipment, and the boiler plant will contain water-tube boilers in units of the largest size available. The boiler settings to be built so as to lose as little heat as possible by radiation from exposed surfaces. All boilers to have tight fitting dampers, which may all be opened from a central point. The oil and steam supply for burners to be controlled from the same central point, and so arranged that burners may be operated from such point. It is also figured that igniters will be fitted in the furnaces which can be operated from the central point, so that fires can be started under all boilers simultaneously.

The boiler capacity in the station is assumed to be such, that maximum load can be carried by forcing boilers 33⅓ per cent beyond builder's rating. This is easily done with oil fuel. Neither economizers nor superheaters will be used.

In connection with the plant will be installed heat storage, consisting of vertical steel cylinders containing water under a temperature due to 200 lb. steam pressure, thoroughly protected with heat-insulating material. The water and steam spaces of these cylinders will be connected with the boilers through automatic stop valves which will open whenever the pressure in the boilers is greater than in the heat storage cylinders. In the heat storage cylinders will be installed internal electric heaters having capacity sufficient to maintain the temperature of the water in them, or, in other words, to supply the heat losses from radiation and convection. The capacity of these heat-storage cylinders to be such, that by reduction of the gauge pressure from 200 to 25 pounds, sufficient steam will be formed to operate the plant at full capacity for thirty minutes. All steam connections to be as short and direct as possible, and all precautions used to keep radiation and condensation losses at a minimum.

On the above assumptions, the following calculations are based:

Rated Horse Power of Boilers Required. The turbines will require at 12,500 kw. load with 175 lb. steam pressure, 28 in.

vacuum, and without superheat, 16.69 lb. of steam per kw-hr. To handle auxiliaries of the plant and the oil burners will require 10 per cent of that required for the main units, or the total maximum amount of steam per hour required will be 459,000 lb. This can be furnished by 11,475 rated h.p. of boilers, working at 33⅓ per cent overload. It is assumed that this boiler power will be installed in 16 units of 720 rated h.p. each.

The amount of heat storage required in connection with each of the above boiler units is calculated as follows:

When the pressure on water under a temperature due to 200 lb. steam pressure is reduced to 25 lb. about 13 per cent of the water will pass into steam at gradually reducing pressure. The assumption was made that the heat storage shall be capable of furnishing steam for the plant for 30 minutes at full load, or 229,500 lb. This is increased by 33⅓ per cent to allow for reduced economy of the turbines with the falling pressure, which calls for 229,500 plus 76,500, or 306,000 lb. As 13 per cent of the water in the storage cylinders passes into steam, they must contain 306,000 divided by 0.13, or 2,353,847 lb. Each of the 16 boiler units will, therefore, need 147,116 lb. of hot water in storage. Assuming the water to weigh 60 lb. per cubic foot at temperature due to 200 lb., the volume of the containers will be about 2800 cu. ft. This volume will be provided by one cylinder, 12 ft. in diameter by 26 ft. in length, allowing steam space over the water. Each of these cylinders will weigh approximately 120,000 lb., and will cost delivered and in place not to exceed 6½ cents per lb., or $7,800. Each storage cylinder will supply 1563 kw. of station capacity, or the cost of storage per kilowatt capacity of plant will be about $5.00. These figures are given to show that the cost is not prohibitive.

Comparisons

Comparison of First Costs. The cost of the gas-making station, as above outlined, is assumed as being $1,000,000, complete with buildings and storage. The figure is based on data procured within the past two years, and if in error, is possibly too low.

The cost of the electric generating station complete, including gas engines, generators, piping, switchboards, wiring, foundations and buildings will be approximately $2,250,000, based on recent quotations.

At these figures, the cost per kilowatt capacity of station for combined gas and electric plant will be $130 per kw.

The cost of the steam-turbine plant complete, including turbo-generators, boilers, heat-storage cylinders, piping, condensers, switchboard, wiring, foundations and building will not exceed $1,500,000, based on recent quotations. The cost per kilowatt capacity of station is, therefore, $60.

The steam-turbine station cost is approximately 46 per cent of that of the gas-engine station.

Comparison as to Rapidity of Getting into Operation on the Line. It has been demonstrated in the Martin Gas-engine station, previously referred to, that one of the large engines can be brought up to speed, its generator synchronized, and connected to the line in 30 seconds. In order that this may be done, however, the operator must be at his station when the signal is given. In the station assumed, 12 engine operators would be required, each at his post, all equally trained to accomplish this, and probably an equal number of switchboard operators. Even then, difficulties in synchronizing such a number of machines simultaneously would probably take a longer time. The expense of keeping such a large operating force as this calls for, is too great to be feasible, and I assume that each operator will handle two engines, and that he will get the two generators on the line in two minutes. I should consider it exceptional work if the entire station could be in operation on the line in two minutes.

In the case of the steam-turbine plant, the following sequence of operations would be followed: The turbo-generators would be operating on the line as synchronous motors to assist in regulating power factor, and with vacuum maintained on the steam ends, with the air pump operating. Steam would be in the main line up to the throttle valves, also on oil-burner line. If current on the line fails, the rotors of the units will continue to revolve for many minutes. Immediately on notice, the operator will begin opening his throttle valves, and energizing his fields from a storage battery, and could easily synchronize the two machines and get on the line within less than two minutes. The air pump, if operated during the period of starting from the storage battery, would require no attention, and if a jet condenser is used, the only requirement in connection with circulating water is that the injection valve shall be opened.

Concurrently with the above, the boiler-room operator will release and open all boiler dampers at one operation, and from the same central point put steam and oil on all burners, and by the use of electric igniters start fires under all boilers simultaneously. The steam pressure in the heat-storage cylinders will gradually

fall until at the end of 30 minutes it will have reached 25 lb. By the expiration of that time, the boilers can be brought to steaming condition under a pressure of 25 lb. or more, and will pick up the load.

I consider that I have reasonably established the fact that the steam-turbine station can be put on the line as promptly as the gas-engine station.

Comparison as to Stand-by Charges. I shall consider this on the basis of the annual stand-by charge per kilowatt of capacity of plant.

Assuming that the fixed charges of interest, depreciation and taxes will amount to 10 per cent, which favors the gas-engine plant, the annual charge against the gas-engine plant will be $13 per kw. and $6 against the steam-turbine plant.

I will assume that the gas-engine station proper can be taken care of by two crews of six men each at the engines, and two at the switchboard, which is certainly more than fair to it. These men will get not less than $100 per month, or an annual pay roll for station of $19,200.

The gas-making plant will also require two crews, each assumed to require six men, which number is an absolute minimum. Their average wages will be not less than $100 per month or an annual pay roll of $14,400. The combined pay rolls will be $33,600, or an annual charge of $1.34 per kilowatt of capacity.

To keep the gas-generating plant in condition such that it can begin making gas with a reasonable degree of promptness, the generators must be kept fairly hot, which will require expenditure of fuel. I have no data of my own as to the fuel necessary for this purpose. Mr. E. C. Jones, chief engineer of the Pacific Gas and Electric Co., informs me that with an expenditure of 150 gal. of oil per day, it is possible to keep a 2,500,000 cubic-foot oil-gas set, at a temperature such that it can be brought to condition for commencing to make gas in 20 minutes. Three such sets will, therefore, take 450 gal. per day. The annual stand-by fuel charge, oil being figured at $1.00 per barrel, will amount to $3,911, or 16 cents per kilowatt of capacity.

It is assumed that the steam-turbine station will require two crews, each composed of the following; two turbine operators, one switchboard man and two firemen. The average monthly wage is taken at $100 per month, which would make the annual pay roll $12,000, or 48 cents per kilowatt of capacity. The heat-storage cylinders will be covered with extra thick heat

insulating covering, around which will be built an enclosing shell of brickwork. It is assumed that the heat losses per square foot of shell, per fahr. degree difference of temperature per hour, will not exceed 0.1 B.t.u. The total surface of all heat storage proposed is 37,728 sq. ft. With a temperature of external air of 70 degrees fahr., the heat loss per hour will be 689,790 B.t.u. The main steam piping that will be under steam will have a surface area of not to exceed 3,500 sq. ft. The loss from this surface is taken as 0.2 B.t.u. per degree difference of temperature per hour, or a total loss on account of such surface of 221,900 B.t.u. The combined loss of 911,690 B.t.u. is equivalent to 359 h.p-hr., or 270 kw-hr.

In other words, it will only be necessary to use a little over 1 per cent of the capacity of the plant to keep the heat storage and main steam pipes up to temperature, as the electric heaters will transform the energy at practically 100 per cent efficiency. I think I may safely state that any of our hydroelectric plants have for at least 22 hr. per day energy going to waste in an amount much greater than 1.1 per cent of the peak load, and that under such circumstances the waste energy should not be considered a charge against the plant. The radiation losses, as above taken, would in two hours reduce the temperature of the water in storage less than one degree fahr., so if no waste energy were available for two hours daily, the effect so far as the value of the heat storage is concerned would be negligible. The original heating of the water, and restoration of temperature of the water in the storage cylinders after a run would be accomplished by the use of steam from the main boilers.

It is assumed that steam will be kept on one 300 h.p. boiler, to operate pumps, to supply steam to burner lines and as an emergency precaution. An allowance of 450 gal per day will maintain pressure on this boiler, and permit the use of 1000 lb. of steam per hour, and at $1.00 per barrel will amount to a yearly charge of $3911, or 16 cents per kilowatt of capacity.

The stand-by charges per kilowatt capacity of the two plants will be as follows:

	Gas engines	Turbines
Fixed charges	$13.00	$6.00
Pay rolls	1.34	0.48
Fuel used	0.16	0.16
Total stand-by charges	$14.50	$6.64

The stand-by charges for the turbine plant are less than 46 per cent of those for the gas-engine plant.

It would be entirely legitimate to make a small charge against the gas-making plant for maintaining steam on one of its boilers, but this has been neglected in the above.

If the entire loss of heat from storage cylinders and piping were made good from the auxiliary boiler, the annual fuel charge for this service would not exceed $2,000.

I believe the above discussion proves my statement that the stand-by losses of the turbine station will be less than for the gas-engine station.

Comparison as to Costs of Continuous Operation. If I have been correctly informed, the manufacturers of the large gas engines at the Martin station, previously referred to, guaranteed them to deliver a brake horse power-hour on 18 cu. ft. of oil gas. No data as to the results acutally obtained have ever been given out, but from such information as I have been able to get, I do not believe that the results are any better than those indicated above.

From a paper read before the Detroit meeting of the American Gas Institute by Mr. E. C. Jones, chief engineer of the Pacific Gas and Electric Co., in October, 1909, I take the following data:

There will be required 8⅓ gal. of crude oil to produce 1000 cu. ft. of gas, and from the process of manufacture there will be a by-product of 20 lb. of dry lampblack per 1000 ft. of gas made, which should be credited to the gas-making process. A portion of the lampblack will be required for generating steam used in the manufacturing process. It is impossible by any method of treatment so far found economically practicable, to reduce the moisture content much below 25 per cent and it is generally fired when containing at least this much moisture. I assume that at least five of the 20 lb. will be used for generating steam, leaving 15 lb. to be credited.

There is no way in which this lampblack can be used in the plant outlined herein for gas-making, although water gas apparatus could be installed to utilize it Mr. Jones in the article previously cited, states that using the lampblack in water gas apparatus, 40 lb. wet lamp-black (30 lb. dry) will make 1000 cu. ft., using 6.8 gal of oil for enriching. As 8⅓ gal. of oil are used for 1000 cu. ft. of gas under the straight oil gas process, each 30 lb. of lampblack saves 1.53 gal of oil, or for the 15 lb. excess produced in making 1000 ft. of oil gas, 0.77 gal. In order to give

the gas-making process every credit it can be entitled to, I deduct this 0.77 gal. from the 8⅓ gal., leaving 7.56 gal. net, chargeable to each 1000 cubic feet of gas made.

If the generator efficiency is 95 per cent, and 18 cu. ft. of gas are used per brake horse power, the amount used per kilowatt hour will be 25.24 cu. ft. The number of kilowatt hours per barrel of oil, from the data above, is 220.1.

To arrive at the kilowatt hours at the switchboard per barrel of oil in the steam-turbine plant, the following assumptions are made: That the average load-factor on the turbines will be 75 per cent when in operation; that the auxiliaries of the plant will require 10 per cent of the steam taken by the main units; that the evaporation of water will be at the rate of 12 lb. per lb. of oil.

The turbine assumed, is one where the steam consumption at three-fourths load will be no greater than at full load, or 16.69 lb. per kilowatt hour. Adding 10 per cent for auxiliaries gives 18.36 lb. of steam required per kilowatt-hour, or at the evaporation assumed, 1.53 lb. of oil. The oil weighs 336 lb. per bbl., and the number of kilowatt hours per bbl. of oil will be 219.6 as against 220.1 for the gas engine. Attendance and fixed charges have been previously shown to be less in the case of the steam plant, so I consider that I have established the remaining statement as to economy made in the earlier part of this paper.

I have endeavored in the argument made to use data and assumptions that in all cases favor the gas-engine station, and feel that on this score I have opened the door to criticism by proponents of steam plants for this class of service.

In closing, I cannot refrain from calling attention to the desirability of fuller information relative to the gas engine station at Martin, which I have previously cited. Judging from current reports it does not seem to have been an entire success. It is said that it is still in the contractor's hands, five years after installation, and that the purchasing company has abandoned it so far as use is concerned. Nothing has ever been published regarding its difficulties and troubles nor as to its economic results, and I hope that in the discussion of this paper those who know the facts will give the engineering profession the benefit of them.

NOTE

The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **San Francisco, May 5-7, 1910.** This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper so far in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, c/o Prof. Harris J. Ryan, Stanford University, Cal.,** so that they will be received not later than May 1, 1910.

A paper to be presented at the San Francisco meeting of the American Institute of Electrical Engineers, May 5, 1910.

(*Subject to final revision for the Transactions.*)

THE DEVELOPED HIGH TENSION NET-WORK OF A GENERAL POWER SYSTEM

BY PAUL M. DOWNING

The greatest incentive to the development and construction of hydroelectric transmission systems has been high fuel costs. This is particularly true in California, where, until the discovery of oil a few years ago, practically every industry using steam as a motive power had to depend on coal imported from Australia or British Columbia.

Owing, however, to the natural advantages due to the topography of the country, the possibilities of utilizing the waters for hydroelectric development were early recognized, and probably more has been done along pioneer lines in this state than anywhere else.

In the preparation of a paper on this subject, therefore, I have confined myself entirely to conditions as they have developed and as they exist in California at the present time, and to the experiences in connection with the different transmission systems, which together form probably the greatest mileage of high-tension net-work to be found anywhere in the world.

On account of the rapidly growing demand for power, it was not possible to wait for results, which, under ordinary conditions could have been obtained from actual operation, but, under the circumstances, things have been done which very conclusively confirm a statement made by Mr. Charles F. Scott in his paper on Electrical Power Transmission, read before the International Electric Congress held in St. Louis in 1904, wherein he states that problems of transmission are not problems that can be solved in the laboratory alone, but the apparatus must meet the precise conditions of operation and be judged by experience.

The first polyphase high-voltage transmission system in the world was the one from Mill Creek to Redlands, a distance of 16 miles. The original installation consisted of three 250-kw. three-phase generators delivering 2400 volts at their terminals, and seven 100-kw. transformers stepping up from 2400 volts to 11,000 volts at which potential power was transmitted to Redlands. The unqualified success of this undertaking almost from its very inception, gave a great impetus to the industry, and within a very few years other installations were made, each with its particular type of apparatus and character of construction.

The Colgate power house of the Pacific Gas & Electric Co. was really the nucleus of the present 60,000-volt net-work, in that it was the first to install apparatus to operate at that voltage, and it was, at the time, the largest and most important hydro-electric station in this part of the state. The history of this plant is unique, in that the generators were installed, in operation, and overloaded, before the construction work on the building was completed.

The system of the Pacific Gas & Electric Co. as it stands today represents the consolidation of a number of smaller companies, each with a system peculiar to itself, and none of them designed with a view of ever tying in with any other system. As a result, almost every type of apparatus from the comparatively small, low voltage, rotating-armature generators, to the larger, more modern, rotating-field, high-speed machines, is represented.

This Company controls and operates eleven different hydro-electric generating stations, having an aggregate capacity of 64,270 kw., distributed as follows:

Power house	Capacity in kilowatts	Generator voltage
De Sabla	13,000	2300
Centerville	6,400	2300
Colgate	13,700	2300
Yuba	600	2300
Alta	2,000	500
Auburn	350	500
Newcastle	900	500
Folsom	3,250	800
Electra	20,000	2300
Deer Creek	5,000	2300
Nevada	1,200	5500

Ten of these have a common frequency of 60 cycles and run in parallel on a 60,000-volt net-work which is also supplied with additional power from four independent companies.

The Great Western Power Co. delivers 60,000 volts by stepping down from its main line voltage of 100,000; the Sierra and San Francisco Power Co., the Northern California Power Co., and the Snow Mountain Power Co., deliver current at 60,000 volts direct.

At times, the load carried by these four companies amounts to an aggregate of 41,500 kw. In addition to the foregoing, we have the following reserve steam and gas engine plants which operate in parallel with the transmission lines when occasion requires; *viz.*, Oakland steam turbine station, San Jose steam station, and Martin gas engine station.

The total reserve capacity at these three stations amounts to 21,500 kw. In Martin station are located two 4,000-kw. frequency changers (from 60 to 25 cycles) which are operated from the transmission line. The 25-cycle side is run in parallel with the 25-cycle gas engine-driven units, and also with the 25-cycle steam-driven station of the United Railroads.

The entire mileage of lines represented by the different systems which are tied together, exclusive of those of 11,000 volts and under, amounts to 1,920 miles.

The voltages of the different lines making up the net work are as follows:

150 miles of 100,000-volt line.
1,390 miles of 60,000-volt line.
380 miles of 20,000-volt line.

It will be noted that lines of 11,000 volts and under are not included in the above for the reason that these lower voltage lines are considered as distributing lines and not as transmission lines.

The paralleling of stations in this manner, regardless of the length of line between them, or the loads carried, has not developed any difficulties, but on the contrary, it has been found that it could be done much more readily than where the generators are paralleled in the same station; nor is it customary to do this paralleling at generating stations alone, or on the low voltage side of sub-stations. As a matter of fact, it is done almost entirely on the 60,000-volt side, using transformers of relatively small capacity connected from line to ground for synchronizing purposes.

The governing and the division of load between the different stations furnishing power to a system of this kind is not as great a problem as it would at first appear. Each station, excepting one, takes its alloted portion of load and makes no attempt whatever to govern, unless the frequency varies beyond certain predetermined limits, the speed control being left entirely to a single station. All important power houses are equipped with governors, which, except in the case of the governing station, are set so that they will be sluggish in their action, and will not operate except on wide variations of speed. Those in the governing station should obviously be adjusted to regulate as closely as possible. The governing is not limited to any one particular station, but it can be done at any station having sufficient capacity to handle the fluctuations of load.

In order to operate, as we do, with a large number of stations running together, we found it necessary to have a chief operator, or what we have seen fit to call a "load dispatcher," who, so far as the details of operation are concerned, is in absolute charge of the entire system. Water cannot be taken out of a ditch or flume, a power house superintendent or foreman cannot shut down a generator or change the load carried on the station. and a line crew cannot work on a line, without first having the approval of the load dispatcher's office. He is at all times in direct telephone communication with every part of the system. and in the event of trouble which might interrupt service, has absolute control of all matters in connection with the re-establishing of service. In his office there is a board showing diagramatically every generating station, transmission line and sub station on the system, together with dummy switches representing every air and oil switch, and the exact position of these switches, that is, whether open or closed. In addition to the record as shown by the board, a very complete log is kept of every detail in connection with troubles of any kind, loads carried by the different stations, and any other matters pertaining to operation.

Telephone circuits are run on all transmission lines, but these are not depended upon for anything more than local use, such as for linemen reporting on and off the line, etc. They do not give satisfactory service when used over long distances, and they become inoperative when there is trouble on the line and when they are most needed.

For communicating between important stations we have cir-

cuits leased from the telephone company, which run on its regular toll line leads, and being over entirely different routes are not affected to any extent by transmission troubles.

Method of Operation

As stated above, the different stations are, for the greater part of the time, operated in parallel. There are two distinct advantages in operating in this manner:

1. The regulation of voltage is much more readily accomplished.
2. The capacities of the different stations can be utilized to their fullest extent.

On the other hand, there is a distinct disadvantage, as trouble on any part of the system will, to a certain extent, affect the entire system.

The inductive drop on the long lines forming a net-work of this kind is obviously high, especially where the induction motor load is heavy, and the power factor correspondingly low. The synchronous motor load represents a very small percentage of the entire load, and there is little opportunity to over-excite the fields and use them as boosters. The wattless current, therefore, becomes quite a problem, and has to be taken care of either by distributing it among the different power houses, or by taking it entirely on a single station, which can be handled very readily by proper adjustment of generator fields.

From an operating standpoint, and in order to better guarantee continuity of service to the more important districts, a reserve steam plant is very essential, and in this respect the modern steam turbine serves the purpose admirably. By reason of the fact that it operates equally well at all loads it can be connected in parallel with the transmission line, and under normal conditions will carry a good portion of the wattless current. At the same time it acts as a stand-by, and in case of line trouble it can pick up the load on very short notice.

Troubles on the long lines forming net-works such as this do not always seriously affect the entire system, but show only as momentary drops in voltage. The station generators are connected directly to the line, without circuit-breaking devices of any kind, and power is never cut off the lines unless it is impossible to keep it on. Immediately on the slightest indication of line trouble, the system is separated, leaving different sections or districts supplied from different sources. If the trouble is far enough removed from the generating station it will not be

very severe on account of the inductive and ohmic drop of the intervening lines, and generally the operators will have time to separate the sections without more than a temporary drop in voltage. If, however, the trouble is near a power house, that particular station will be thrown out of synchronism with the system, and even the machines in that station may be thrown out of synchronism with each other.

Connection

The greater number of the lines feeding into the system are supplied from transformers delta connected on the low-tension side and star connected on the high-tension side, with the neutral grounded.

This arrangement has proved very satisfactory, and while it might be said that there is a disadvantage in using such a connection on account of the grounding of one wire throwing a short-circuit on the system, yet there is a question as to whether or not this is a real disadvantage.

If all lines could be run through sparsely settled districts, or where there would be little liability of damage to persons or property were a wire to come down, there would, doubtless, be some advantage in operating with a delta connection, but where lines are run along public highways and through more or less thickly settled districts, it seems almost necessary that there should be some very positive indication to show when a wire goes down.

Some objection has at different times been raised by the telegraph and telephone companies to a grounded neutral system, on account of the inductive influences due to current through the ground, at times when the load is unbalanced. Experience, however, has shown that this is not the real cause of the trouble, but that the troubles these companies have are the result of what might be called static unbalance, or high-frequency disturbances due to arcing grounds, or other causes which occur to a greater extent in an ungrounded system than in one where the neutral is grounded, and therefore at zero potential. This statement is borne out by experiments that have been made on telephone circuits paralleling or carried upon the same poles as the transmission wires, where loads aggregating as high as 3,000 kw. have been transferred from three to two transformers of a bank, or vice versa, with practically no effect on the telephone service other than slight change in the tone of the line.

Our usual practice is, where one of three transformers in a bank at the generating end is out of service, to carry load up to the capacity of the other two, or should occasion demand, to over-load the two, making them carry the normal load of the three. It is not necessary to limit the unbalancing of power delivered to the line in this manner, and we would have no more hesitation in cutting out one of a bank of three 1500-kw. transformers than in cutting out one from a bank of three 100-kw. transformers. This same condition obtains in the case of step-down transformers. When the load to be supplied is small, and where the expense of installing three, or even two transformers to give a three-phase distribution would not be justified it is customary to install a single transformer, connecting it from the line wire to ground. Installations of this kind ordinarily give no trouble whatever, but work as satisfactorily as though a bank of three were installed. Careful attention must always be given to the ground connection. These are made by connecting to the water mains, and also to ground plates buried to a depth depending on the character of the soil.

Occasionally it has been found where only a single transformer is used, that a severe static stress occurs on the low-tension side, which is severe enough to puncture the insulation of the lower voltage transformers supplied from the main transformer. These instances, however, have been comparatively few, and while it is something which might be expected from a connection of this kind, it very seldom occurs, and it has never been serious enough to make it necessary to abandon the practice.

The connection on the low-tension side of the step-down transformers is either delta or Y, depending entirely on the particular voltage condition to be met. Where the Y connection is used, the neutral is grounded in the same manner as on the high-tension side, and to the same ground wire.

So far as the actual operation of the system is concerned, there is no preference as to the connection on the low side, but for economic reasons the greater number of low-tension distributing systems are supplied from the Y-connected transformer. We have never yet had any troubles which we could trace back and find to be the result of the manner in which transformers were connected.

Transformers

The capacities of transformers used, range from 100 to 1500 kw. Most of them, except some of the smaller sizes, are shell type,

oil-insulated, and water-cooled. The most satisfactory case for oil-cooled transformers is one of boiler iron mounted on a cast iron base and having a cast iron top.

A great deal of discussion has been heard concerning the merits of the different insulating materials used in transformers for high voltage work, the kind of oil to be used, and the methods of cooling the oil. During the past few years the tendency of the transformer manufacturers has been toward the use of a press board or horn fibre for the insulating barriers between the coils, this material being used to replace the micanite used in the earlier transformers. This gives a transformer of lower first cost but one correspondingly less staunch and reliable.

The micanite insulation has two distinct advantages; first, it will not absorb moisture as readily as the pressboard or horn fibre; and second, being non-inflammable, it will localize trouble, and a burn-out in one coil, unless it be exceptionally bad, will not damage adjacent coils. Until a few years ago all of the transformers on the system had micanite insulation. They would be received from the factory, and without attempting to dry them out, they would be filled with oil and put into service. The oil was generally shipped in iron drums containing from 50 to 100 gallons, and when received, it would be put into the transformer without treatment of any kind, and even without being tested to see that it had the proper dielectric strength. The pressboard has superseded the micanite, and the methods of handling transformers have entirely changed. We now find it necessary to dry them out thoroughly even after they have been standing without oil for not more than ten days or two weeks. The oil also is being handled much more carefully than formerly, and separate samples taken from the different tanks in which it is shipped, must be tested. If the dielectric strength is found to fall below a certain standard, it is safe to assume that the low insulating qualities are due to moisture, which can be readily removed by heating to a temperature slightly above 212 degrees fahr.

The pressboard or horn fibre will not only absorb moisture from the atmosphere, but it will, when in direct contact with water, absorb sufficient of it to allow the layers of fibre making up the sheet, to separate, thus rendering it worthless. This objection to its use might on first thought seem hardly worth considering, but in practice it is an important one. In handling transformers out of doors during stormy weather, or in the

event of a damaged water coil allowing water to get into the winding, the pressboard would be damaged to such an extent that the transformer would have to be torn down and the barriers replaced.

As to the relative fire risks of air- and oil-cooled transformers, I think that it is now generally conceded that the oil type with a properly designed case is the safer of the two.

The greatest danger from an oil-insulated transformer is from fire external to the transformer itself, which might damage the case and allow the oil to escape.

In a number of instances there have occurred fires which have heated the boiler iron cases to such an extent that the oil has been badly carbonized and the paint on the inside of the case burned entirely off without damage being done to the winding. After removing the damaged oil and cleaning the winding, the transformers have been refilled with new oil and immediately put back into service without trouble. In one particular instance which I have in mind, a fire occurred in a wooden switch gallery almost directly over a bank of 700-kw., transformers which at the time were not in service. Before water could be turned on the fire the transformers had become very hot, and when water was finally turned on, the cast iron tops had become so hot that the water coming in contact with them, damaged them beyond repair. The windings of the transformers were uninjured, and after being dried out were put back into service and are operating to-day.

From the view point of the man who has to operate the transformer, particularly in connection with long high-voltage lines, I am inclined to question the advisability of attempting to sacrifice the reliability of the transformer in order to cut down the first cost. In the absence of any approved device or apparatus that can be relied upon to take care of high-voltage line disturbances, the transformer must bear this burden to a very great extent, and the breaking down of a transformer with the resulting interruption to service, will, in a very short time more than offset any saving in first cost. For this same reason the three-phase transformer is at a disadvantage, as trouble on one phase would entirely interrupt service, unless a spare were installed.

For cooling the oil we employ the usual method of circulating water through copper coils immersed in oil. Different metals have been used in these coils, but on account of there being less liability of copper being acted upon by acids in the cooling water,

and also because of the fact that it will not corrode, it has been found most satisfactory. In localities where there is any great amount of mineral in the water, a cooling coil will in time become filled to such an extent that it will not carry a sufficient amount of water to cool the transformer. This deposit closely resembles boiler scale, and in some instances it can be removed by taking the coil out of the case and hammering it on the outside to loosen the scale, after which it can be blown out by either steam or compressed air. In cases where it cannot be removed in this way, we have used dilute muriatic acid as a last resort, but as this acts upon the metal of the coil, as well as upon the scale, it cannot be considered entirely satisfactory.

Periodic pressure tests are made on all cooling coils without removing them from the transformers, and very often without taking voltage off the transformer. This we do by disconnecting both ends of the coil and allowing the water in the lower turns to either drain off; or, if both ends of the coil come up over the case, a small rubber hose is inserted on the riser side of the coil and the water syphoned out. To know that the coil is thoroughly dry, and that in the event of its breaking down under pressure, no water will get into the transformer winding, a light blast of air is passed through the coil, which, with the heat from the oil on the outside of the coil, will in a very short time remove any moisture which might remain. One end of the coil is then plugged and air pressure applied by means of an ordinary automobile tire pump. A small pressure gauge connected to the coil shows the pressure on the coil, and also whether or not there are any leaks which would allow the pressure to drop. Generally where there is no back pressure on the coils, 15 to 25 pounds will be as high a test as is necessary.

Switches

Outside of the lightning arrester or line discharger for taking care of high voltages, high-tension switches were probably slower to develop than any other piece of apparatus used in connection with long transmission lines. It is only during the past few years that there have been any high-tension switches on the market, but there are now a number of different designs, all of which have proved generally satisfactory.

The system of the Pacific Gas & Electric Co., was one of the first to use oil switches for voltages in excess of 40,000. As early as 1900 we built and put into operation, switches which were of practically the same type that we are now using. While

the switch was in the experimental stages, the frame work supporting the tanks were of wood, and the tanks themselves were the ordinary fibre or paper mache tubs such as are used for laundry purposes. Switches of this kind served their purpose well, and are even now in use after years of service, but where they are called upon to break heavy loads, such as come on at times of short circuit, they are apt to throw the oil out of the container when operated.

To overcome this trouble, we designed a four-break switch, along practically the same lines, but with a considerably greater depth of oil over the contacts. Four-break switches similar to the one shown in Figs. 1 and 2, have been in service in some of our largest power houses for several years, and they have never failed to open the line under all conditions of short circuit.

The particular features which recommend this switch are:

1. The absence of any insulating material that might become saturated with oil and catch fire either from leakage or from an arc.

2. The insulation of the switch from the ground, thereby affording the greatest protection against break-downs due to surges or other high-voltage disturbances when the switch is open.

3. A constant depth of oil over the contacts at all positions of the blades.

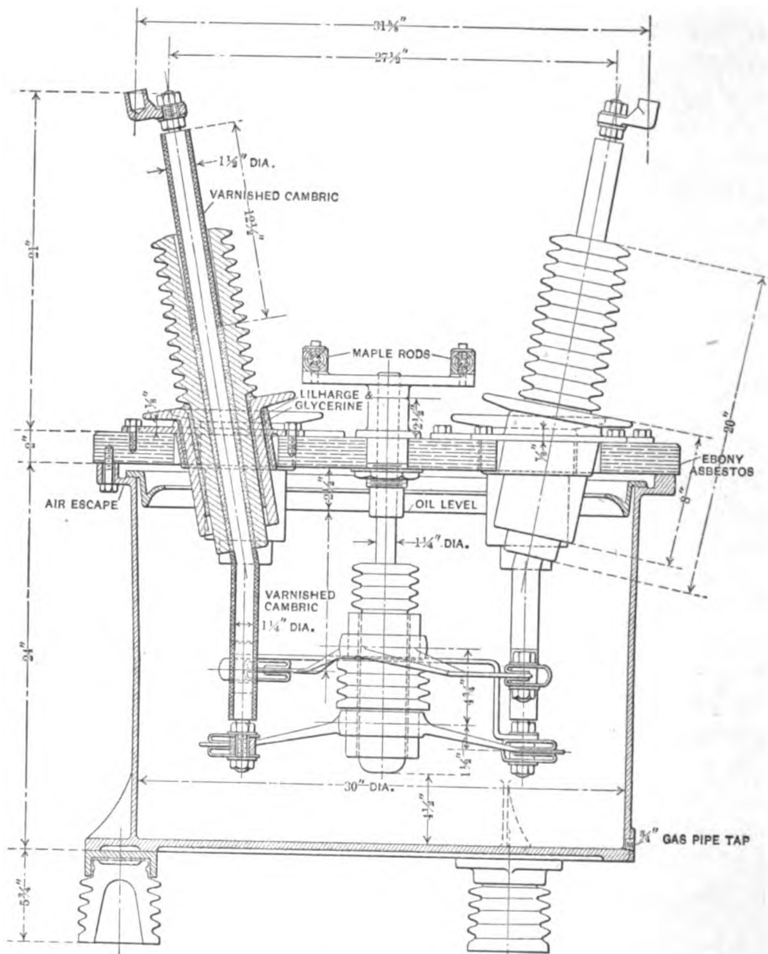
4. The comparatively small amount of space taken up by the switch.

We have never attempted to operate any of these high-tension switches either automatically or by any electric or pneumatic means, preferring rather to keep to the more positive hand-lever control. This control has generally proven quite satisfactory, but we have just installed some reverse current relays to be used in connection with the automatic operation of switches on lines which are tied together at both ends. We have yet to learn to just what extent these can be successfully employed, on account of the inherent weakness of alternating-current reverse-current relays, whose operation is dependent on both current and voltage, and the fact that in cases of severe trouble the voltage may drop so low that the relay will be inoperative.

Lightning Arresters

Except in the higher mountain districts the Pacific coast is comparatively free from lightning, and we make no attempt whatever to protect against lightning disturbances.

On most of the early installations, lightning arrester apparatus, such as was on the market at the time, was installed at different points along the line. Practically every type of multigap arrester was tried, all of which proved to be a menace rather



SECTION ON A-B

FIG. 1—Elevation of high-tension switch

than a protection on account of their arcing over whenever there was a heavy line disturbance. The result has been that long since they have been abandoned, and we now use only the horn-gap type arresters with the air-gap set so that they will arc

across on voltages approximately 25 per cent above normal. The particular design of arrester used, consists of two gaps in series with the ground side, connected directly to earth without resistance.

These are used more on account of their being voltage limiting devices than on account of their being a protection against high voltages. Discharges over these arresters always cause a drop in voltage, and very often a momentary interruption to service until the arc breaks. We do not install them at every station,

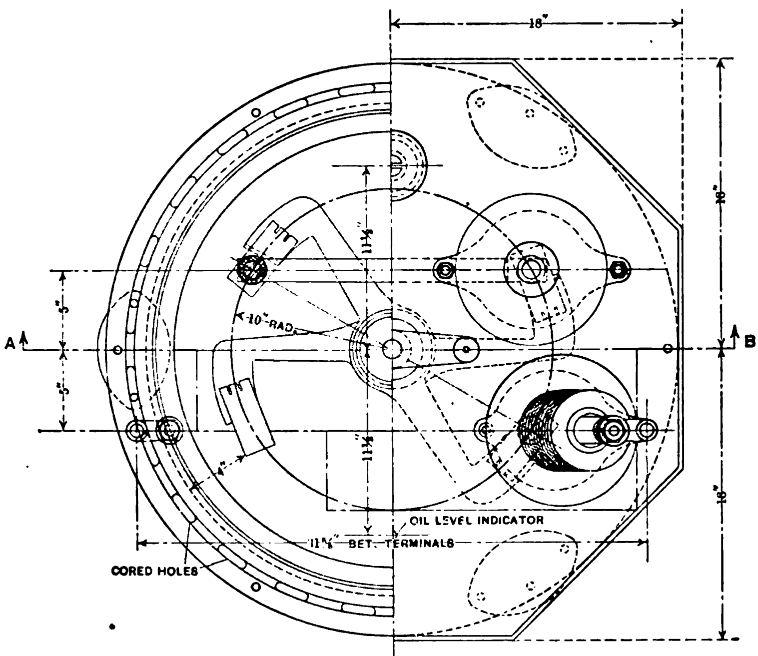


FIG. 2—Plan of high-tension switch

but only at the power houses and more important stations where heavy switching is done. The electrolytic arrester now on the market has been installed on some of the lines in this state but as they have been in service only a short time, little can as yet be said concerning their efficiency or effectiveness.

INSULATORS

The question of line insulation for the high voltages now being used on transmission lines, is the most serious problem

engineers have to face, and while it is true that both the design and quality of the insulators manufactured to-day are far superior to those of a few years ago, it is also true that the limiting voltage of a transmission system is governed by the insulators.

The climatic conditions of the greater part of the Pacific coast are peculiar in that there are two seasons, one wet and one dry; and it may seem strange to say that the insulator trouble during the dry season, or just when the first rains start in, is as much as or more than there is during the winter storms. The trouble is due to leakage over the surface of the insulator on account of the dirt and the salt which is deposited by the ocean fogs. As soon as the heavy rains come, this accumulation of dirt, etc., is washed off, and the number of insulator troubles is materially reduced. The number of insulators that actually puncture are very few, the greatest trouble being due to leakage. As a striking illustration of troubles of this kind, I might state that insulators operating successfully at 60,000 volts in the mountain districts outside of the fog belt, and where there is little or no dust, give a great deal of trouble on 11,000-volt lines in the bay district where they are exposed to more severe conditions of dust, fog, and smoke.

Troubles of this kind generally affect insulators on grounded and ungrounded structures differently. If they are supported on poles where the leakage path to ground is a high resistance one, the top of the pole will be burned off, and generally the insulator is not damaged. But where metallic structures or grounded pins are used, thus giving a low-resistance leakage path to ground, the insulator is more often damaged by the arc, which very often is great enough to burn off the line wire.

Troubles of this kind naturally bring up the question of what design of insulator will best meet the conditions, and whether or not the theory that as much of the insulator as possible should be kept dry is a correct one. This theory has been carried out in the vertical or pin type insulator with the result that in the three- and four-part insulators a good portion of the inner petticoat is protected from the rain and cannot be washed by the elements. It therefore becomes necessary to shut down the line and wipe them by hand. This cleaning is especially necessary in the fog district near the bay and along the coast, where it has to be done about twice each year. The suspension insulator has a decided advantage in this respect, in that a much

greater part of the surface of the insulator is exposed to the rain and dirt, and is washed off during stormy weather. However, with the higher voltages at which this type of insulator is designed to be operated, there is every reason to think that similar troubles will be experienced, and doubtless the same homely means will sooner or later be resorted to in order to overcome it.

NOTE

The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **San Francisco, May 5-7, 1910.** This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper so far in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, c/o Prof. Harris J. Ryan, Stanford University, Cal.,** so that they will be received not later than May 1, 1910.

A paper to be presented at the San Francisco meeting of the American Institute of Electrical Engineers May 5, 6 and 7, 1910.

HYDROELECTRIC POWER AS APPLIED TO IRRIGATION

BY JOHN COFFEE HAYS

Introduction

Among the many uses to which hydroelectric power is being applied, that of electrically pumped water for irrigation is being advocated at present in a great many instances; and while the mere pumping of the water is so simple as to be hardly worthy of discussion, it may be of interest to point out some of the operating conditions encountered in a project formed chiefly for this purpose.

A hydroelectric system to supply power for pumping water for irrigation will usually be required to build up its own market in the territory served, and it is manifestly necessary at the outset to carefully study the territory. Usually some pioneer work by progressive farmers will show what the land is capable of producing, but the greater part of the territory will consist of barren country planted to grain, or used for grazing purposes, with here and there a town. This land is in large holdings, and the first thing to be determined is the amount of sub-division which may be expected, and whether the proper men are in the field to bring this sub-division about. The character of the land, is of course, of primary importance and the percentage of good land should be carefully determined. Irrigated land should have a slight slope for distributing the water and must be reasonably smooth. Hard pan near the surface must be guarded against, as it generally denotes a rather poor quality of soil. The adaptability of the soil for different products and the climate should be considered, yet data on these two points are hard to get and are usually unreliable. Tests and analysis of the soil would seem to be the natural way of determining its

adaptability to the different products, but the agriculturist pays very little attention to these analyses, and has apparently a good reason for this, as they are often unreliable.

In the San Joaquin and Sacramento valleys it has been demonstrated that almost any kind of products may be raised on the good lands. Only a small portion of this land has been planted to citrus fruits, but small groves may be found along the entire length of the valley, and it would therefore seem as though it were all adapted to this class of products if water is applied. The best conditions seem to exist, however, where the mountains rise abruptly from the valley, and the level flat land extends up to the foothills, for, where a long stretch or rolling country lies between the plains and the hills, hard pan and bed-rocks are generally very much in evidence.

Due to the fact that the oranges in the San Joaquin valley ripen and are marketed a full month earlier than those in the southern part of the state, they bring exceedingly good prices, and the growth of this industry is very rapid. The present citrus districts, as in fact is most of the land in the citrus belt, are above the existing irrigation canals, which in most instances divert all of the water available from the rivers, and are therefore entirely dependent on ground waters for irrigation; and, as the profits from this crop warrant a large expenditure, it is naturally the best market for power for pumping purposes. Aside from citrus fruits, all kinds of high-class products, such as deciduous fruits, berries, vegetables, nuts, vines, and alfalfa are to some extent also irrigated by pumped ground water.

The amount of water required for the irrigation of different products varies to such an extent in the different communities that it is impossible to get any figures which would be at all accurate. The character of the soil is accountable for the difference to a large extent, but the cost of water and the personal equation are accountable to a very much larger extent. There is usually a marked tendency to the over-use of water. The duty of irrigation water in California is believed to average about 2 ft. in depth in addition to the average rainfall.

In the Imperial valley, in 1906, 120,000 acres were irrigated and a total average depth of 2.04 ft. was used, the main crop being grain. In San Diego county on land planted to citrus fruits an average depth of 1.5 ft. was used from 1889 to 1899. Around Los Angeles it is estimated that an average depth of 2.4 ft. is used.

In the Modesto and Tyrlock districts as much as 8 ft. to 10 ft. in depth was used at the start, but in 1908 the depth varied from 1.2 ft. to 3.6 ft. In the Fresno district very little water is applied to the surface of the land at present, the land being sub-irrigated by seepage from the canals.

Comparison of Gravity and Ground Waters

Where gravity waters are available this method of irrigation is usually much cheaper than by ground waters, and will consequently be used in preference. However, the difference in price is not as great as is popularly supposed, and the cost of irrigation in the case of high-class products is really one of the small items in the total expense, and therefore the use of ground waters may show advantages which will easily offset the difference in actual cost. Ground water irrigation has the following advantages all of which are of considerable importance:

First, the duty of water is higher, due to the fact that it is more economically used on account of the cost of pumping, and the water that is not evaporated and absorbed by the products again sinks into the ground to replenish the underground supply and be used over again.

The second advantage is the drainage function, as the over-use of surface water has, in many cases, ruined excellent land by causing the raising of alkali to the surface, and thousands of acres of the finest lands in the large irrigation districts have been waterlogged and ruined by the excessive use of gravity waters.

The third advantage of ground water irrigation is the freedom from weed seeds which are often carried by ditches and canals, and which, if they do not actually ruin the property, greatly increase the cost of cultivation.

The fourth advantage which the pumped water has is its convenience, and the absolute independence of the farmer using it. The matter of taking turns at the water, and having to use it when you do not want to, and not being able to use it when you do want to, or trouble with the man further up the ditch taking all the water in the dry season and flooding you out in the wet season is entirely done away with where ground waters are used.

The writer has found it impossible to obtain any reliable information regarding the cost of gravity water irrigation except from the large irrigation districts, and even this is incomplete.

The large irrigation districts in Central California are not fully developed, and to take care of the lands which are not yet irrigated, but which are paying their portion of the irrigation tax, reservoirs must be built. The drainage of these lands may be counted upon to cost as much or more than the irrigation. In the case of the small ditches practically no record of costs is ever kept. The cost of litigation is another large item which may be charged to practically every ditch and canal system. Taking all these things into consideration, it will be seen that, even where actual cost is concerned, the pumped water may compare very favorably with surface water in cost, and in fact, there are instances where it is actually cheaper.

The only argument aside from the less expense that the writer has heard advanced in favor of the surface water irrigation is the fact that the surface water may be a better quality, it being nearly always soft and pure, while the ground waters are sometimes hard, and in some cases alkaline and injurious to the products. There are, of course, cases where these conditions exist when the use of ground water is out of the question.

Where intensive farming is practiced and the ground waters are entirely depended upon, some concern has been felt as to the sufficiency of the underground supply, and undoubtedly many localities could be found where more water would be withdrawn from underground basins than is restored by natural process. The Lindsay district is entirely planted to citrus fruits and other high-class products requiring a large amount of water. Every drop of water used for irrigation, domestic and stock purposes is pumped from the ground, and the water level averages a depth of 60 ft. to 70 ft. when pumping. It would seem that the Lindsay section should show a diminution of the ground water supply, if it is to be a serious problem, as it is probably the most disadvantageously situated district in the county in this respect, yet the water after twelve years of heavy pumping is standing as high in the wells as ever. It is also to be noted that the wells are not what might be considered deep, their average being about 150 ft. to 200 ft., and, as the cost of pumping is insignificant when compared either to the profits or to the expense of the grove, it is apparent that much deeper wells may be indulged in if the waters show signs of decreasing, and within certain limits, the deeper the well the more water.

The San Joaquin and Sacramento Valleys are also favorable storage basins for ground waters, as the only outlet is the San

Francisco bay through the narrow straits of Corquinez. The elevation of the Lindsay district two hundred and fifty miles away is about 300 ft., and the ground waters must, therefore, of necessity travel very slowly and be in large quantities.

Development of System

In determining the policies and the scope of a proposed hydro-electric system for the supply of power for pumped irrigation, it is necessary to determine at the outset the exact territory to be served and the general policies to be followed as regards charges, contracts, extensions, etc., or, in other words, a definite goal must be set, the power company must do everything possible to assist development, and any inhabitant in any section of the territory must be supplied with power whenever it is required. Therefore, the power system simply grows up with the country, and while this growth is taking place (it of necessity must take many years), it must be considered that the power system is in course of construction during the entire period. This is the main feature in which the power project depending entirely upon an irrigation market differs from the project supplying ordinary commercial business in an already well settled community, and this is a difference which is seldom fully understood and the time element not fully provided for.

The initial installation will usually cover various towns and communities, and, if the territory is partially developed, the development will probably be close to the towns. The business available may, therefore, be fairly well concentrated at the start, and consequently profitable as far as it goes, but naturally only a small amount of the ultimate power required will be marketed. The extensions to the system will be made from these towns, and the fact that development of the community always starts near the town and grows outward is a most favorable condition of affairs for a power company. The price of land is always greatest near the towns, and decreases in proportion to the distance from any center, yet the land near the town is the first developed. These towns are built along the railroad, and being the shipping points, the reduced cost of hauling to the railroad to a certain extent offsets the additional cost of the land.

The Hydroelectric System

The character of construction of a system depends entirely on the class of market, and for irrigation a slight discontinuance of service is not serious, therefore a light construction is per-

missible. The generating stations at the outset should be of a fairly permanent character, but the distributing system may and actually should be of a light and in many cases even bordering on a temporary character, as it is necessary to economize in every way at the outset to warrant the low rate which it is necessary to charge in order that the market may be developed; for it is necessary at the outset to establish a rate which will continue in effect when the system is fully developed. Even the expense of the generating stations may be reduced to a considerable extent at first, and as the system increases and the market becomes concentrated, improvements of a more permanent nature may be added.

Notwithstanding this, the writer has heard engineers of standing make the broad statement that there was no excuse for the use of a wooden flume and that a tunnel was the only proper thing; also that certain plants were altogether too flimsy and temporary in their design, and that the wooden pole line was entirely obsolete. When these statements are made, the writer cannot but think that the assertions are prompted by a lack of regard for the first principle of engineering, namely, economy. Every one who has had any experience with the wooden flume knows the many interruptions of service caused by it, yet, if constant service is not absolutely necessary, what possible type of construction can compare with the flume. It is short lived, but several can be built for the cost of a tunnel, and during the early life of a transmission system every dollar counts. If the system warrants a tunnel, it may be constructed durng the life of the flume to take its place. Of course, if the systems depends entirely upon one power plant, the replacement of the flume is both difficult and expensive, but few existing systems of any importance rely entirely on one plant, and there is usually sufficient capacity available during certain periods of the year to allow for the shutdown of one station. Also an auxiliary steam plant is often cheaper than a tunnel and much more useful.

Wooden pole lines are also perfectly reliable in our California climate and are a very worthy substitute for the steel tower lines in respect to business development, and there is nothing to prevent the construction of the tower line when the wooden pole has outlived its usefulness; no interruption of service is necessary, as the right of way should be wide enough to accommodate both lines.

Among the different parts of the system where considerable

expense may be saved is the switching gear, which may be extremely simple at the outset and still ample. A small galvanized iron building on a wood frame is a thoroughly satisfactory building for the pioneer substation, which can be replaced by a permanent and fireproof structure when the business warrants. By the construction of light, inexpensive tie lines one substation may be arranged to temporarily supply the territory of another, and by the construction of a ring system many miles of expensive transmission line may be replaced by a much lighter class of construction, which will answer all purposes for many years.

In the greater part of California the conditions are ideal for long pole spacing. High winds seldom occur and sleet is unheard of, but it is not uncommon to see a line consisting of three wires ranging in size from No. 2 to No. 8 supported by poles spaced from 120 ft. to 150 ft. apart. However, on new lines, the fallacy of this mode of construction is apparently being realized, and much of the new work looks different. In one case the writer has seen a pole spacing of over 500 ft. in use on light lines, 40-ft. poles being used, which made a very nice appearing and businesslike line. Due to the less number of poles used, better poles, cross-arms and insulators may be indulged in. Other details may be treated in a similar manner.

Description of Typical System

The writer has been connected for several years with probably the only hydroelectric power project that depends almost entirely on pumped irrigation for a market, approximately 70 per cent of the power generated being used for this purpose, the balance of the power being used for the ordinary commercial purposes in towns and settlements within the territory served, and for the operation of one interurban railway. The entire territory, however, is supported by the agricultural and horticultural products, and, therefore, the system is believed to be almost as nearly an exclusive power pumping system as can be imagined. The actual conditions obtaining on this system should apply closely to conditions which may be expected in other similar projects.

Territory. The territory of the company referred to comprises approximately 1,050 square miles in Tulare and Kern counties, California, being a strip of country about 50 miles long north and south, and 22 miles wide. The only available

gravity waters for irrigation are the waters of the Kaweah and Tule Rivers, all of which have been long ago appropriated.

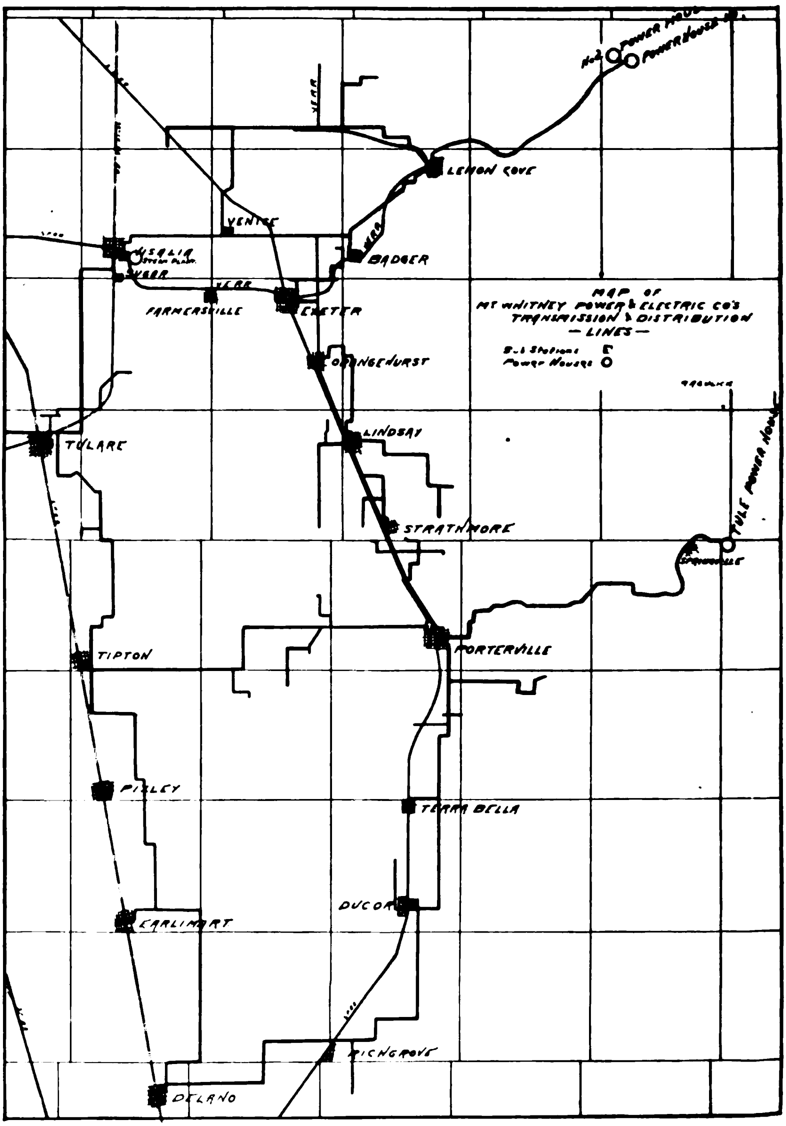


FIG. 1

This gravity water irrigates about 90,000 acres of land and the balance of the territory, or approximately 560,000 acres, must depend entirely on the ground waters for irrigation before they

can be made to produce other than grain or pasturage. The average annual rainfall for the territory is about 10 inches, and the soil and climate are admirably adapted for the production of all kinds of high-class products. The territory may be for convenience divided into two sections, the citrus belt comprising approximately 200,000 acres of land, and what may be termed the valley portion. In estimating the power requirements it is considered that approximately half of the land in the citrus belt will be planted to products requiring approximately half as much water as the citrus fruits.

Forms of Contracts and Charges

The bulk of the power is sold under three forms of contract, all being for a period of five years or longer. The contract under which the greatest amount of power is marketed, and which is used by the orange grower, is called the "continuous" rate and provides for the supply of current at the flat rate of $50 per h.p. per year, as measured at the peak load at any time during the season.

The second contract, called the "spring and meter" rate, applies to other classes of products, such as deciduous fruits, alfalfa, etc., and provides for the supply of power at a flat rate of $25 per h.p. for the period from February 1 to July 31, when the meter is cut in and all current used during the remaining six months is charged for at the rate of 3c. per kw-hr. The minimum payment during the meter period is $1 per h.p. installed, per month, thereby bringing the minimum charge to approximately $31 per h.p. per year, the flat rate charge being based on the maximum demand. In nearly all cases where this contract is used the annual consumption is not in excess of the minimum. as the total amount of current the consumer is entitled to under the minimum may be used at any time during the meter period. The cost of pumping under this form of contract varies directly with the rainfall, but the minimum will be sufficient for the average season. This contract is used to a considerable extent on land which is irrigated by gravity waters, which are not sufficient in the dry seasons, and is in this way used as an auxiliary or an insurance. Most consumers, however, prefer the regular flat rate contract, and the "spring and meter" rate is seldom used in this district except in the case of a young grove, where less water is required. The exclusive use of this form of contract for irrigation would, however, be of advantage to a power company

where steam power is used as an auxiliary during the dry season, as the operating ratio would be more uniform under these conditions.

The third long term contract applies to power for miscellaneous commercial purposes not pertaining to irrigation and consists of a meter rate with a graded base rate according to the season of the year. For motors having a capacity of less than 20 h.p. an addition is made to the base rate according to the size of the motor, to motors from 20 to 50 h.p. the base rate applies, and for motors from 50 to 100 h.p. a subtraction is made from the base rate. The minimum payment is $1 per h.p. per month for the rated capacity of the motor. This method of charge, while somewhat complicated, works out very satisfactorily in practice, as will be observed from the fact that practically all other kinds of power have been displaced in the territory. The reason for adopting such a rate will be apparent by a study of the load curve and the curve of stream flow. Naturally most consumers can not regulate their demands for power in such a way as to use the greatest amount during the time of the low rate and economize during the time of the high rate, but the general effect is good and a marked tendency toward the desired results is being obtained.

Aside from the above contracts, lighting rates and a monthly power rate are in force, but include no special features.

Under the pumping contracts, it is to be noted that the same rate is made on any size motor, which is most important, as the sub-division of the land into small tracts is necessary for the success of any community, and the small grower should receive all the encouragement possible.

The above contracts all include the following provisions, which are somewhat out of the ordinary:

1. All contracts are acknowledged before a notary public and recorded.

2. All contracts are an absolute lien on the property of the consumer, the property being accurately described in the contract.

3. The consumer grants the company a right of way over any part of the property described.

The use of the current is limited to the land described in the contract.

5. All delinquent accounts bear interest at the rate of 1 per cent per month, compounded monthly.

6. The minimum charge under the flat rate contracts is for 75 per cent of the rated capacity of the motor.

The advantages of the above provisions are as follows:

No. 1 is explained by those following.

No. 2 protects the company against all bad debts and takes the place of the often-used meter deposit. In connection with No. 5 it allows the company to carry the account of some hard pressed consumer longer than might be otherwise done, as the security, is amply sufficient. There are also many cases where the consumer prefers to pay the interest charge, if he can allow his account to run until the returns from his crops are received.

The third clause is one over which considerable trouble was experienced at first, but is nevertheless the most important one to the company, for, in a country where roads are few and far between, it is continually necessary to cross over private property, and the right of way over the property of one consumer allows for the construction of lines to serve his neighbor. The objections raised to this clause were that the company would have a right to run lines all over the consumer's property and might run right through his front yard or over his house, if it wished, but these objections gradually died out, for the company in all cases takes the path of least resistance, the consumer being consulted where it is necessary to run over his land, and the lines are constructed in accordance with his wishes, even though this is not always the shortest way across. It is also the aim to run all transmission lines on section lines, for it is considered that there should be a county road around each section and that eventually there will be. The company has a franchise over all county roads and naturally uses them wherever possible. The land owners have, therefore, been shown that the right of way privilege has not been abused, and that in all cases where their land has been crossed it has been for the benefit of their neighbors.

Nos. 4 and 5 are self explanatory.

No. 6 is incorporated to encourage the use of the proper size motor for the service required. An electric motor operated at full load feels dangerously hot to the layman, and it is apparently the natural tendency of the farmer to purchase a larger size motor than is needed. The determination of the proper size motor is a simple matter, and a partially loaded induction motor has a power factor that does not do a transmission system

any good, so the 75 per cent of the rated capacity minimum payment is rigidly enforced.

By the installation of a double throw switch, the flat rate consumer is allowed the use of current for lighting purposes when not using the motor, ten 16-c.p. lamps being allowed for each horse power contracted for; but, of course, this lighting is confined to the residence of the consumer. The grower generally provides a motor of one or two h.p. capacity for pumping water for domestic use, the pump operating in the day time and the lights at night. Lighting is the only use of current allowed under these conditions, although small household appliances, such as a fan motor, flat iron, vacuum cleaner, etc., may be used. Electric heating and cooking, however, are not allowed, the regular meter rate being used for this purpose.

Load Characteristics and Power Required for Pumping

The load curve, Fig. 3, together with the connected load, Fig. 2, will show better than any individual examples the amount of power which is required for a large territory with varying water levels ranging from a few feet to 90 ft., and with lifts above the surface at the wells varying from two or three feet to several hundred feet, there being approximately 18,000 acres of land under pumped irrigation at present.

It is estimated that one horse power used in the ordinary way during the respective irrigation seasons will irrigate an average of five acres of citrus fruits and 10 acres of other products in the citrus belt, and 16 acres of deciduous fruits, alfalfa, etc., in the valley section.

The following table was compiled from observation at typical pumping plants on the system. In the table the letters at the head of the columns signify as follows:

A. No. of acres of oranges.
B. Average age of orange grove.
C. No. of acres of vines.
D. No. of acres of alfalfa.
E. Horse power capacity of motor.
F. Horse power tested.
G. Depth of water during pumping season.
H. Height water is raised above surface of ground at well.
I. Total head.
J. Acres per installed horse power.
K. Estimated depth of water available over land if operated continuously during pumping period based on 50 per cent plant efficiency.

Plant	A	B	C	D	E	F	G	H	I	J	K
1	30	3	—	—	5	5	86	4	90	6	2.9
2	40	3	—	—	5	3.0	66	4	70	8	1.8
3	54	15	—	—	12	12.1	50	5	55	4.5	6.3
4	50	3	—	—	7.5	5.2	45	5	50	6 7	4.2
5	16	13	—	—	5	4.7	87	·3	90	3.2	5.1
6	20	13	—	—	5	4.5	65	5	70	4.0	5.7
7	22	12	—	—	5	4.7	65	5	70	4.4	5.1
8	10	10	—	—	2	2.4	66	4	70	5.0	4.5
9	48	11	—	---	10	9.1	70	5	75	4.8	4.4
10	40	5	—	—	5	4.6	—	—	80	8.0	2.3
11	33	3	—	—	15	12.9	30	100	130	2.2	6.2
12	16	7.5	—	—	10	10	20	100	120	1.6	8.2
13	110	2	—	—	27.5	27.6	40	5	45	4.0	8.8
14	70	3	—	—	15	15	80	—	80	4.6	4.2
15	35	6	—	—	10	7.8	40	—	40	3.5	8.8
16	135	5	100	—	85	69	20	80	100	2.7	4.6
17	66	3	—	—	10	9.7	40	—	40	6.6	5.8
18	111	2	—	—	15	15.8	27	5	32	7.4	7.1
19	140	7	—	—	50	50	60	90	150	2.8	3.6
20	145	7	—	—	50	32.8	60	87	147	2.9	2.4
21	—	—	30	—	15	12.8	28'	2	30	2.0	18.8
22	120	10	80	—	47.5	40.1	50	—	50	4.2	6.3
23	—	—	74	—	15	16.2	35	5	40	5	7.2
24	—	—	—	240	10	7.0	0	8	8	24	3.9
25	—	—	—	160	5	5.6	0	16	16	32	3.5
26	—	—	—	260	15	19.2	16	5	21	17.2	5.5

The above table might be extended and averaged to show the horse power and water required for the supply of various products and for the requirements of orange groves of different ages, but there are so many variable elements entering into each case that any such figures, even if based on an average of every plant on the system, would be, in the writer's opinion, practically worthless. In the case of the high lift plants water is usually taken from the main pipe at different levels, but, as the current is charged for at the maximum demand rate and as the pumps are designed for the highest head, only the high head is taken into consideration.

Fig. 2 shows the increase of connected load on the system from 1903 to 1909, inclusive, for power and lights. This curve does not show the railroad load, which is 600 kw. and was connected in February, 1908, and operates at a load factor of approximately 30 per cent throughout the year. Of the total connected power load at the end of 1909, there was 3,776.75 h.p. used for the pumping of water, leaving 573.25 h.p. for commerical power purposes. This applies to all motors over ½ h.p., sizes under this being included in lighting.

Fig. 3 shows the average monthly load curve at the generating stations for 1901 to 1909, inclusive. The shaded portion of this curve represents the load on the auxiliary steam plant, made

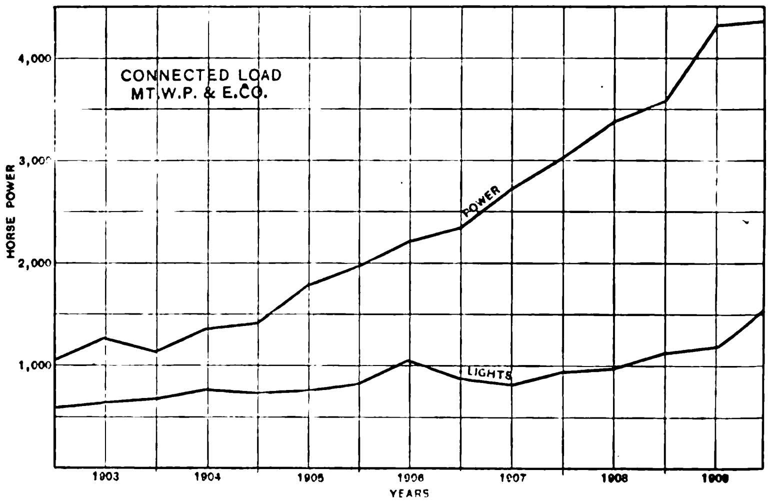


FIG. 2

necessary in 1908 by the disabling of one generator in No. 1 power house and an extremely low water period of the rivers; and in 1909 the steam plant floated on the line until the Tule

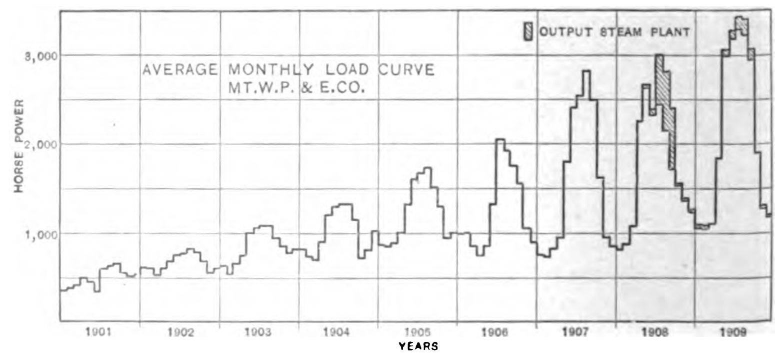


FIG. 3

river plant was completed late in the season, the other power stations being fully loaded.

Fig. 4 shows the load curve for the maximum demand during the years 1907, 1908 and 1909. It will be noted that the maxi-

mum demand at the power stations is very much less than the connected load, regardless of transmission losses, although the pumping load is considered extremely steady during the irrigation period, the pumping plants operating 24 hours per day at as near the full capacity of the motor as possible. The lighting load has no appreciable effect on the generating stations during the time of maximum demand, as it is balanced by a certain amount of power used only during the daylight hours.

Fig. 5 shows the load factor of the system, and this also clearly

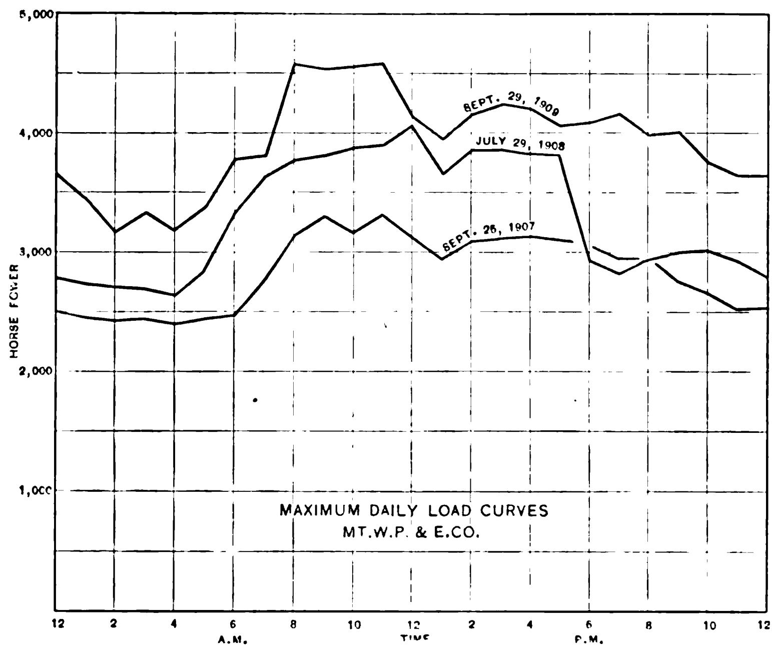


FIG. 4

points out an important condition to be considered in an enterprise of this character, as it is comparatively low. This curve shows that a large amount of power is available for market during the winter and spring months, and with such market obtainable, the capacity of the generating stations could be greatly increased, as the flow of the rivers is greatest at this time.

Fig. 6 shows the characteristic flow of the streams during a very dry season, and is a combined curve of the Tule and Kaweah rivers. All of the rivers flowing into the San Joaquin valley

have the same general characteristics, and a comparison of the load curve and this curve of stream flow shows the time of heavy load during the period of low water, and the generating plant

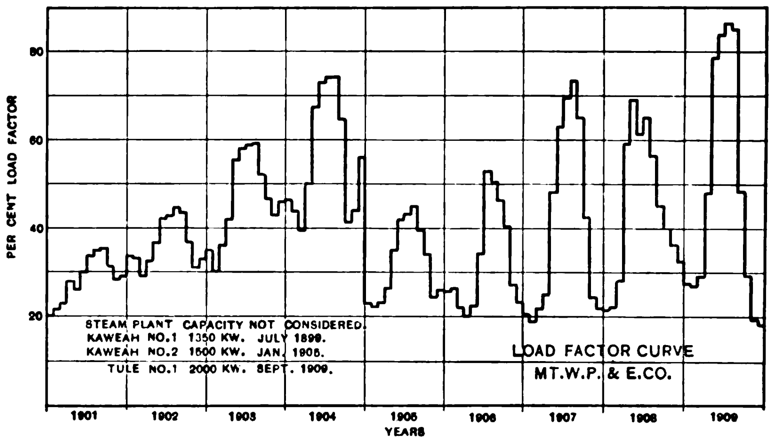


FIG. 5

must, therefore, be designed for the minimum flow of the stream unless suitable storage reservoirs are available. These reservoir sites are available on some of the streams feeding the valley,

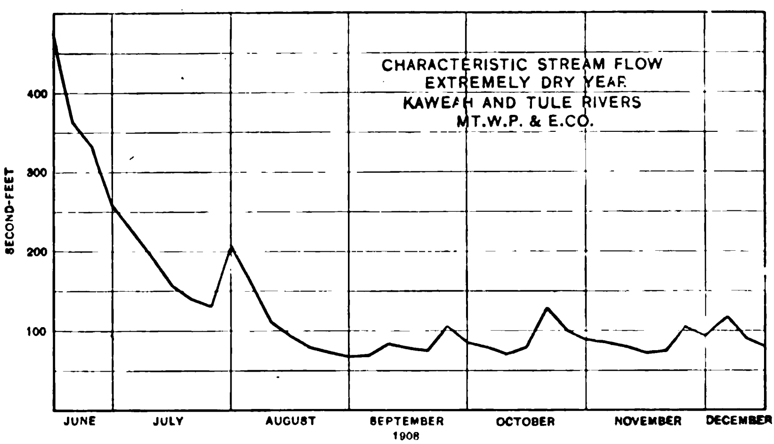


FIG. 6

but are scarce and expensive to develop, and the plants are designed for the minimum flow.

In connection with the load factor curve, it is to be noted that

when the load factor reaches approximately 50 per cent it is necessary to construct an additional plant.

Generating Stations

The generating stations consist at the present time of three hydroelectric power plants having an aggregate capacity of 4,850 kw. and one turbo-generator steam auxiliary plant having a capacity of 1,000 kw. Two of the water-power plants are on the Kaweah river and one on the Tule river, the steam auxiliary being in Visalia, the principal town on the system. The fourth water power plant, which will have a capacity of 3,000 kw. will also be on the Kaweah river.

Power house No. 1 was the first constructed, and diverts the waters of the east fork of the Kaweah river through six miles of redwood flume. The plant was constructed in 1899, and the flume is to-day perfectly sound and will last at least 10 years longer before it will require replacement. The static head obtained is 1,310 ft. and the generators are driven by overhung wheels on the generator shaft. The equipment consists of three units of 450 kw. each, two belt-driven exciters, and four 500-kw. transformers, one being a spare transformer. The transformers are oil-insulated and were designed to be self-cooled, but additional cooling is obtained by pumping the oil through coils on which water is sprayed. The transformers are located in individual compartments entirely separate from the power house, as are also the lightning arresters and high-tension switches.

Regulation is manual, controlling stands being situated in front of the switchboard, two of which operate deflectors which regulate the amount of water applied to the wheels by deflecting the stream, and one of which regulates the water supply to the third machine by a needle nozzle. At the penstock a regulating reservoir in the form of a large flume has been constructed, having a capacity of 25,000 cu. ft. The main function of this reservoir is to smooth out the daily variation of stream flow, as, due to the method of regulation at the power house, no great economy of water can be practiced, although the needle nozzle allows the regulation of water to some extent. Since the other plants have been constructed, however, no regulation is done at No. 1, which simply takes a certain load and holds it.

Plant No. 2 was constructed during 1904 and put into operation in January, 1905. The water for this plant is diverted from

the main Kaweah river, and is conducted to the penstock through 15 flumes aggregating 0.87 mile, and 3.1 miles of ditch. The flumes are all redwood and the ditch is concrete lined, the ditch construction being used where the slopes will permit, the flumes being constructed on the rough broken ground and to cross ravines. A concrete lined penstock reservoir is excavated in the side of the hill having a capacity of 75,000 cu. ft. The static head is 360 ft. and the power house equipment consists of three units of 500 kw. capacity, each direct connected to high-head turbines regulated by Lombard governors. Two turbine-driven exciters are installed, which are hand regulated. Seven 350-kw. step-up transformers are installed in compartments outside of the power house, one being in reserve. The transformers are cooled in the same manner as those at No. 1 by circulating the oil.

The No. 3 Kaweah plant, on which construction is just started, will divert water from the main Kaweah river, which after passing through a conduit 10 miles long, will discharge just above the intake of No. 2, thereby using the water twice. The static head of this plant will be 1,960 ft.

The transformers at Nos. 1 and 2 are arranged on trucks so that they may be easily run into the power house under the crane for repairs, etc., if necessary. In No. 1 individual tracks are run from each transformer, and in No. 2 a transfer truck is run on the track in front of the transformer compartments, so a transformer may be pushed out on to the transfer truck and taken to a short piece of track entering the power house. The switching gear in both stations is arranged so that the spare transformer may be immediately cut in in place of any other transformer.

The buildings at both Nos. 1 and 2 are constructed of corrugated iron on wood frame; foundations, floors and transformer compartments being constructed of concrete. The corrugated iron structure is, for all practical purposes, ample, as the climatic conditions are most favorable, and a protection from rain is about the only requirement necessary. These buildings are, however, cold in winter and hot in summer, and would not be considered strictly permanent or fireproof.

The third, or Tule river plant, was constructed in 1908 and 1909, and started operation in September, 1909. The water is diverted just above the junction of two forks of the river, there being two diverting dams and headworks from which short flumes lead to a point at approximately the junction of the river, and join. The water is conducted to the penstock through

4.5 miles of pine flume, 2.06 miles of concrete lined ditch and 880 ft. of inverted siphon pipe, the siphon working under a 5-ft. head and having its lowest point 120 ft. below the conduit grade. This siphon was used to cross a long gulch.

The ditch is lined with concrete and excavated well into the mountain, very little reliance being placed on the filled bank, the water level being only 6 in. above the natural level of the downhill slope. The ditch is 4½ ft. wide and 3 ft. deep, the sides sloping 1 to 1. It is lined with concrete 2½ in. thick, over which ½ in. of cement plaster is applied. A small amount of alum was mixed with both the concrete and the plaster, which renders the lining practically water tight. Due to the steep slope of the mountain side and the size and depth of the ditch, the sloping of the upper bank to a slope of 1 to 1 required considerable excavation. However, the finished product is a most permanent piece of construction. The flume is of the standard bent and stringer construction, the bents being placed 16 ft. apart, and a strip of burlap saturated with an asphaltum compound is placed under the battens for waterproofing.

At the penstock a regulating reservoir is excavated in the side of the mountain. A small portion of the upper end is 5 ft. deeper than the balance of the reservoir and is used as a sand-trap. The reservoir is 12 ft. deep, 350 ft. long and of an irregular shape, varying from 12 to 125 ft. in width, following the contour of the hill. The side slope is ½ to 1, and it is lined with 8 in. of concrete and ½ in. of plaster. A concrete wall at the end separates it from the penstock.

The reservoir has a capacity of 175,000 cu. ft., which will operate the plant 1¾ hours at normal load. Therefore, in the case of a break in the flume, sufficient time will be available to start the steam auxiliary plant without interruption of service. The reservoir also has sufficient capacity to regulate the daily fluctuation of stream flow during the low water period, so that the highest use may be made of the water. The static head is 1,135 ft., and the whole plant is designed with a view of ultimately doubling the present capacity.

The power house equipment consists of two 1,000-kw. units with overhung wheels, Lombard governors, directly actuating needle nozzles, an auxiliary nozzle being provided which automatically opens in the event of the main needle nozzle closing too quickly and ramming the pressure pipe. These auxiliary nozzles, when opened, close at a predetermined speed regulated by the dashpot principle. This arrangement allows the most economical

use of the water. Two exciters, each of sufficient capacity for both generators are installed, one being driven by a water wheel and one by an induction motor. Seven 400-kw. water-cooled transformers are placed in the transformer room on one side of the power house, one transformer being held in reserve. Lightning arresters and high-tension switches are in a separate building.

The power house building and arrangement differ from the other plants in several respects. The power house is constructed of ferroinclave on a steel frame; the ferroinclave being plastered on each side with 1½ in. of cement plaster, therefore making a reinforced concrete roof and sides 3 in. thick. A partition of the same thickness divides the generating room from the transformer room and a similar partition divides the transformer room into two compartments, fireproof doors completing the separation. The switch house is constructed of the same material, and both buildings have metal window casings and wired glass windows, no wood being used in the construction. The above may seem inconsistent after the statement that the other power house structures were practically sufficient, and this would be the case, were it not for the fact that the transformers which present a certain fire hazard are placed in the power house building. Also the company has passed the pioneer period, and can, consequently, afford a little more permanent construction.

The switching gear and wiring has been greatly simplified by connecting the transformers in two banks, the spare one not being connected. The transformer "railway system" is also dispensed with simple rollers being provided instead. In the event of an accident to one transformer its bank may be disconnected, the leads removed from the affected transformer, water pipes disconnected and the transformer skidded to one side. The spare transformer can then be skidded into place and connected up and the entire job performed in about one hour, certainly a short enough time for a system of this character.

In connection with all of the power stations, the question of the operator's comfort has been given proper attention. From a practical business point of view, this is a paying investment, as a much better class of men can be procured. Comfortable cottages are provided, the surrounding grounds are cultivated and a small ice plant is a part of the standard equipment. A few fruit trees and a garden will not only greatly improve the looks of the property, but will also greatly reduce the boarding house expense.

Transmission System

As shown in Fig. 1 the transmission system is in the form of a figure 8 or a double ring. In this way current is available at both sides of any sub-station, thereby giving all of the advantages of duplicate lines. The main transmission line from power houses Nos. 1 and 2 feed in at the northeast corner of the system and the line from the Tule river plant feeds in at the center of the system. The steam auxiliary is in the northern ring and can consequently feed both ways. The old transmission lines have wires spaced 36 in., the sawed redwood poles being spaced 120 ft. apart. The new transmission lines in the valley consist of a double circuit, the 34,000-volt lines being placed on one side of the pole and a 6,600-volt distributing line on the other side. The circuits form equilateral triangles, the apex of which point downward; the wires are spaced 36 in. apart on each circuit. The main line from the Tule river plant consists of one circuit, the poles being of cedar 35 and 40 ft. in height and spaced 300 ft. apart. On all new lines a pole spacing of from 300 to 420 ft. is used, with 35- and 40-ft. poles, depending on the character of the country.

The current is distributed from 12 substations situated in the various towns and settlements, and the transmission and distribution systems are laid out to provide for additional substations as the load increases. The substation construction varies, all but one having started in the same way, namely, as a cheap wood or galvanized iron building with the most simple switching apparatus, and, as the substation grows in importance, substantial brick buildings are constructed with more or less elaborate switching gear, storerooms and offices.

The power is distributed at 6,600 volts and 2,200 volts, two-phase, the first distributing being at 2,200 volts; 6,600 volts eventually proved more satisfactory on the power circuits. The city lighting systems distribute at 2,200 volts, two-phase, with the exception of two new systems, where three-phase has been adopted. There are 246 miles of 6,600-volt line, 53 miles of 2,200-volt line, and 28 miles of lighting circuits of 2,200 volts and about the same length of low-voltage line with a connected load of 1,190 kw. of lighting transformers. The consumer supplies the secondary transformers for power supply and the power is measured on the primary side of these transformers.

Effect of Power Pumping on Land Values

While some exception may be taken to the statement that the development in this section is due almost entirely to the applica-

tion of electric power for pumping purposes, it is, at the same time, believed to be the case, and this seems to be proved by the land values where pumped irrigation has been established.

Unimproved lands lying south of Porterville sold in 1890 for from $5 to $7.50 per acre, in 1900 for $10 to $15 per acre, and in 1909 for $60 per acre and higher. Lands north and east of Lindsay, which sold in 1895 to 1900 at from $35 to $40 per acre, now sell at $150 per acre. The assessed values of two sections, one three miles north-east and the other one mile west of the town of Lindsay, show that in the first instance the assessed value was $14 per acre in 1890, $36 in 1899 and $91 in 1909, and in the second instance $19 in 1890, $36 in 1899 and $117 in 1909. The above figures represent about the average conditions, there being many cases of increase where the figures have been greatly exceeded.

Investment Value of a Power Irrigation Project

The application of a hydroelectric system exclusively for the furnishing of power for pumped irrigation from an investment point of view is not of the get-rich-quick variety. The investor who wishes to receive immediate results on his money should not enter into any such scheme, unless the power company owns the lands to be put under irrigation, when the project develops into a real estate transaction, the power part being insignificant. Where the project is confined wholly to a power proposition, it should be gone into only by the most conservative investors or developers and pioneers who are content to bide their time and be satisfied for many years without dividends, but with the increased value of their investment. The power company must indirectly meet the opposition of other irrigation districts, and the large government projects, as well as the opposition of gasoline engines and other power, and the charges for service must be as low as possible.

The territory served is sparsely populated at the start, and usually no irrigation is indulged in except by some few scattering pioneers, who may be using gas or steam engines and windmills, and the marketing of power, therefore, depends entirely on the rate at which the territory served is put under high-class cultivation; and this is a slow process. To support a project of any magnitude requires an immense territory, and in the early years of development it is not unusual to construct a line five or ten miles long to supply a motor of as many horse power; for any part of the territory must be supplied regardless of its loca-

tion with reference to existing lines, and everything must be done to encourage the development of the entire territory taken as a unit, and, for the first few years, even though the territory is settled rapidly, it can not be hoped to make the power project pay.

The power company after a few years should show a profit above interest charges and operating expenses, but for every dollar earned several more must be expended on extensions, and, while it is true that, after the system commences to show earnings a great many extensions may be taken care of by bonds, these always require a certain amount of money to be provided by the company. If the development is rapid the stockholders are often required to subscribe additional money aside from the earnings, and must in many cases content themselves solely with the increased value of the property. The increased value of the property may be large and the investment, as far as security is concerned, be of the finest, as it usually is; but in this day of progress and quick returns on investments it is rather difficult to find many investors who are content to wait a generation before receiving any actual cash returns on their money, no matter what the company's books may show as to earnings or as to increased value of property.

When the system is fully developed and loaded the dividends may be large, and the reliability and permanence of the market will often place the stock almost on a bond basis, and in this way a carefully planned and developed hydroelectric system for the supply of power for pumped irrigation may be considered a splendid investment, but never in the light of a speculation. It must be clearly outlined at the inception of the enterprise just what is to be accomplished, for it is a long job and one which requires a great deal of looking into the future.

The final results must be arranged for years before they are obtained and everything shaped to this end. A desire to hasten the marketing of the power may set some precedent which would be most difficult to overcome, and the failure to provide for emergencies may undo the work of years and completely demoralize a system. An overloaded system is to be particularly guarded against, as too much valuable produce depends entirely on the service, and any damage to the producer may completely stop development and stifle the entire community. The power company, therefore, has a very large moral responsibility to face, which is not to be lightly considered.

DISCUSSION ON "SOME PHASES OF TRANSFORMER REGULATION." SAN FRANCISCO, OCTOBER 29, 1909

(*Subject to final revision for the Transactions.*)

F. E. Geibel: The paper tonight has been very interesting, more so because we have had actual tests from which the conclusions have been drawn. As explained, the action of transformers in groups, or in banks, depends on the action of the single phase transformer, and the authors have touched briefly on the single phase transformer and meter potential transformer before going to the banks.

Unbalancing on the banks of transformers, as we have seen, is largely taken care of by the induction motor and synchronous apparatus. Again, in the case of power transformers, or transformers for delivering power, we are not so much concerned in the phase angle difference; what we want on the other side is voltage, and with as little drop as possible. As the regulation is affected at high power factors mostly by the resistance, and at low power factors mostly by the reactance, in a well designed transformer,

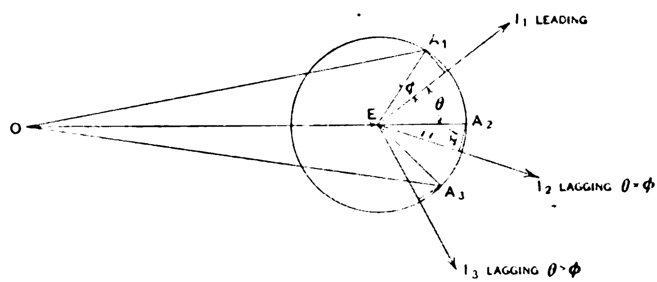


FIG. 1

both are kept as low as possible. In the case of the meter transformer, however, the phase angle difference between the secondary and primary e.m.f's. plays a more important part and affects considerably the wattmeter readings.

The authors have found that, in the meter transformer under test, the equivalent resistance is about twice that of the equivalent reactance. Since the power factor of an alternating current circuit is the cosine of the angle whose tangent is x/r, we have for the power factor of this transformer, 0.91 approximately.

In the accompanying diagram $O\,E$ represents the secondary e.m.f., $E\,I_1$, $E\,I_2$ and $E\,I_3$, the secondary current at different power factors, and A_1O, A_2O and A_3O the corresponding primary e.m.f's. From the figure it is seen that on passing from leading current to lagging current, the angle of lag exceeding the angle of lag of the transformer, we pass from a condition of lagging to a condition of leading phase angle difference between primary and secondary e.m.f's., the two e.m.f's., being exactly

180 degrees apart when the power factor of the load is made the same as the power factor of the transformer.

The power factor of a meter load is approximately 0.75 to 0.8 and on the meter transformer under discussion, a load of this character would give a condition of leading phase angle difference. Thus, while the poor regulation of the transformer would cause a wattmeter to indicate low, the leading phase angle difference decreases the angle between current and potential and causes the meter to indicate high—the two effects to a large extent neutralizing.

The meter transformer, although not showing up so well when regulation alone is considered, has been found to be very accurate, especially when used on loads for which they have been designed.

In the July number of the PROCEEDINGS Mr. Robinson has gone into this matter very thoroughly and has also taken into account the phase angle difference of the meter itself.

W. F. Lamme: The problem of transformer regulation is usually a very important one. As noted in tonight's paper, there are three elements to be considered:

First—The ohmic resistance.

Second—The inductance.

Third—The leakage flux.

In the paper is given a case in which large flux leakage takes place, with certain connections. But in every transformer there is a slight leakage between the primary and secondary coils, and this leakage is different in different transformers, and even in different arrangements of coils in the same transformers. The more closely interlaced the primary and the secondary coils are, the better is the regulation, and vice versa. In other words the more perfectly the magnetic flux set up by the primary coils is forced through the secondary coils, the better the regulation. This is, or should be, a question of considerable interest to all engineers. But, I believe, definite information upon the subject is largely confined to factory circles.

It is interesting to study the regulation of transformers with non-inductive and with inductive load. With a non-inductive load the regulation of a transformer is, of course, nearly equal to the ohmic drop, and the inductance has little effect. With an inductive load the inductance of the transformer comes into effect, and the effect of the resistance is lessened, depending upon the power factor of the load. From the above it may be inferred that the regulation of two transformers may be different with non-inductive load, and nearly the same with inductive load.

In recent years more care has been given to this question of regulation for lower power factor. The point just mentioned is best illustrated by two sets of curves. One showing the regulation of a series of transformers from one to fifty kilowatts operating with non-inductive load. The second curve showing the same transformers operating with an 80 per cent power

factor load. In these sets of curves are three types of transformers. A core type, a shell type, and one of the newer types of transformers. At 100 per cent power factor you will note all of the types agree very closely in regulation, taking them size for size. But the regulation is poorer the smaller the size of the transformer. All this is natural, and to be expected, for economical design limits us to this condition. But at 80 per cent power factor the regulation of the same sizes are wide apart. And the regulation of the older type is quite erratic, whereas the regulation of the two newer types are not so erratic. Also note that the newer types have nearly the same regulation from the smaller to the larger sizes.

As to transformers for operating meters, we note from the paper that these transformers are compensated for the conditions under which they are supposed to operate. This is important. If the transformer is compensated to operate say, one wattmeter, correctly, the same transformer will not operate two wattmeters correctly. And in the second case there may be an error of several per cent. Therefore, in the purchase of such transformers, it should be the practice of the party purchasing the same to name the conditions of operation.

Combinations of transformers to change from three-phase to two-phase, or from two-phase to three-phase, are made at the expense of regulation, as well as at a loss in efficiency. By the example in the paper, you see that it is important to know how to make some of these combinations properly. Otherwise the regulation and losses will become excessively bad. And, as a result, there may be a burnout of one of the transformers.

Mention was made in the paper of unbalanced primary voltages and their effect on the secondaries. This is a very important matter, especially in power transmission work. In such work we rarely see balanced conditions on the delivery line. Sometimes the unbalancing is very bad. I have in mind one case of a 30-h.p. three-phase induction motor operating from three 10-kw. transformers. One of the three transformers burned out without apparent cause. Our investigation showed the division of load between the three transformers as follows: First, 14 kilovolt-amperes; second, 10 kilovolt-amperes; third, 6 kilovolt-amperes. The 14-kilovolt-ampere transformer burned out, due to unbalanced condition of line. The above transformers were at first connected delta to delta. They were changed to delta primary, star secondary, after which the loads divided much better than they did at first.

B. G. Lamme: The authors of the paper of the evening have called attention to the unbalancing or distortion of voltage and phase which may be obtained with various unsymmetrical combinations of transformers. They have also stated that induction motors tend to reduce such distortions. It may be added that synchronous motors and converters also tend to reduce the distortion. But all such correcting effect is obtained at a certain expense, usually in the capacity of the correcting apparatus.

Distortion of phase, and of voltage, both tend to produce unequal currents in induction and synchronous motors, including converters. If one leg of a supply circuit is of higher voltage than the others, while the motor generates equal counter e.m.f's., current will so flow in the motor that the motor e.m.f's. are distorted in the direction of the line distortion, while the currents tend to correct the line e.m.f. The limit is when the line and motor come to balanced condition with respect to each other.

This unbalancing in the currents affects the capacity ot the motors. The total copper loss may not be greatly increased, but the losses in individual coils, or circuits, will be changed. At the limiting capacity of the motor, the heating of individual coils fixes the rating, as a rule, and not the loss as a whole. Any unbalancing in current, therefore, affects the heating of the individual coils, and thus reduces the limiting capacity. This is true for induction and synchronous motors. But for synchronous converters the case may be still worse.

In converters, the armature copper loss is normally much less than with a corresponding direct-current machine, or if the converter was run as a straight direct-current generator. This is due to the fact that the same winding is used for the incoming alternating current and the outgoing direct current. Part of the alternating current input is fed directly in the direct current, while part is transformed to mechanical energy, and back to direct current electrically. In consequence, when transforming three-phase to direct current, the armature copper loss is only 57 per cent of straight direct current operated with same armature while with two-phase (or four-phase in reality), it is 38 per cent, and with six-phase it is 26 per cent. But this 26 per cent loss is not uniformly distributed in the armature. The average loss in the various armature coils depends upon their position with respect to the tap-offs to the collector rings. The highest loss is next to the tap-off, this being about 60 per cent of direct current Therefore, the coil next to the tap-off is liable to be overheated under extreme condition of load.

If the power factor is not 100 per cent, then this loss curve is greatly affected. At about 95 per cent the loss in the tap-off coil goes up about 100 per cent. And at still lower power factor it goes much higher. Therefore, a low power factor greatly reduces the ultimate capacity of a converter, depending upon the size, and general design of the windings, number of phases, etc. Unbalanced voltages or phases, due to unsymmetrical transformer combinations will have a bad effect on the capacity of any converter, and care should be taken, with such machines, to furnish balanced supply conditions.

The fact may be of interest that 60-cycle synchronous converters, as a rule, can be operated at lower power factors than 25-cycle converters as normally constructed. This is not due to any peculiar merit of 60 cycles, but is due to the fact that 60-cycle converters usually have many more poles than 25-cycle, and it parallel wound, as is usually the case with large sizes, the smallest

armature strap conductor which is safe for mechanical reasons, is much larger than necessary for electrical purposes.

It has been found in practice where unsymmetrical transformer combinations have been used for step-up purposes, that a similar arrangement should be used for stepping down. For instance, if the Scott, or T combination is used to step up from two to three-phase, then a T should be arranged for stepping down to motors, with the head of the step-down T across the same wires as the head of the step-up T. The same is true of other unsymmetrical combinations. In this way some of the inequalities cancel instead of accumulate.

In connecting unsymmetrical transformer combinations in parallel, there is usually a possibility of cross currents between them, unless all are arranged across the polyphase lines in a similar manner.

In conclusion it may be said that all unsymmetrical systems should in general, be avoided. Such systems originate, as a rule, in an attempt to save in first cost of a system or installation, but in the end they are generally much more expensive than true balanced systems, when reduced capacity of apparatus, etc., are taken into account.

J. W. White: In regard to the inquiry on the effect of frequency changes upon the accuracy of primary recording wattmeters, and particularly upon a 60-cycle meter operating upon a 25-cycle circuit, I would say that in the first place the potential coil of the meter would probably burn out on account of the excessive current. The potential transformer might do likewise, as the capacity of a 60-cycle transformer operating on a 25-cycle circuit is but 69 per cent of its rating, due to excessive magnetizing current. However, if this did not occur the meter would run fast.

Consider first the potential transformer.

In the ideal potential transformer the phase displacement in the secondary circuit would be offset by a capacity effect, and in Fig. 2, $O\,E$ or $O\,B$ would be the impressed e.m.f. and $O\,a$ would be the effective e.m.f.

If, however, the phase angle of displacement is leading or lagging, a condition will exist similar to $O\,B$ or $O\,BB$. If operating on a lower power factor, $R\,I$ would remain constant with $X\,I$ diminishing in proportion to the frequency. If $O\,E$ and $O\,a$ coincide, a lowering frequency would have no effect inasmuch as the inductive reactance is offset by the capacity effect and thus the effective e.m.f would be higher and the amount of compensating effect in the transformer's secondary winding can be less.

If, however, the reactance effect in the transformer is leading or lagging to produce $a\,BB$ or $a\,B$, then the phase displacement of the transformer is equal to $BB\,O\,E$, or $B\,O\,E$.

If, as in Fig. 2, $(BB'\ a'')$ the power factor of the circuit (not the transformer) passes from leading current to lagging current, the angle of lag exceeding the angle of lag of the trans-

former, the angle of phase distortion with reference to the secondary is further increased, while on the other hand if the power factor of the circuit is leading and the power factor of the transformer lagging the two would tend to compensate and cut down the angle of phase displacement.

The same condition would exist if the opposite were true, *i. e.* if the angle of phase displacement of the transformer were leading and the power factor of the circuit were lagging the two would tend to compensate, while if the power factor of the circuit were leading the resultant phase angle with reference to the secondary of the transformer would be greater.

From the above it is at once evident that in lowering the frequency $X\,I$ would be diminished and whether leading or lagging would cause the angle $B\ a\ E$ to be decreased and thus reduce the angle of phase displacement.

From the above can be deduced that lowering the frequency of a potential transformer will tend to reduce the phase angle of displacement if leading or lagging. (This would, if any

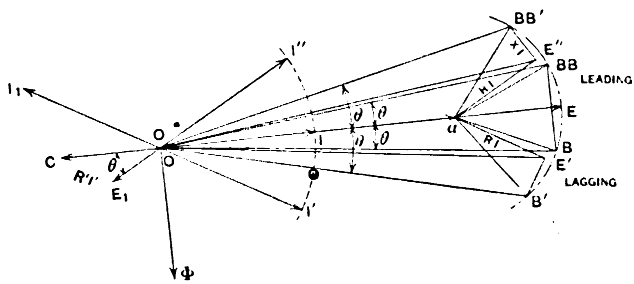


FIG. 2

thing, cause the meter to run faster.) If the transformer capacity is balanced by the inductance there will be relatively no change.

With regard to the regulation of the transformer and the effect of the resistance of the coils upon regulation, let the line I represent the harmonically varying flux in the core. $O\,a$ represents the useful part of the primary electromotive force and $O\,c$ the total electromotive force induced in the secondary coil. The line $O\,I$, represents the secondary current and the line $O\,I''$ represents the primary current. The total primary electromotive force E' exceeds $O\,a$ by the amount $R\,I$ (parallel to I') and the electromotive force E, at the terminals of the secondary coil falls short of $O\,c$ by the amount $R'\,I'$ parallel (to I_2).

When the angle θ ($a\,O\,I'$) is nearly zero (secondary receiving circuit non-inductive) then $R\ I$ and $R'\,I'$ are nearly parallel to Oa and $O\,c$ respectively, so that $O\,a$ is much less than E' in value and E' is much less than $O\,c$ in value. On the other hand, when the angle θ is nearly 90 deg. (secondary receiving circuit containing a large inductance of a condenser) then $R\,I$ and $R'\,I'$ are nearly perpendicular to $O\,a$ and $O\,c$ respectively, so that $O\,a$ is nearly

equal to E' in value and E_1 is nearly equal to $O\,c$ in value. Therefore the regulation of a transformer is largely affected by coil resistance when the secondary receiving circuit is non-inductive, but scarcely at all affected by the coil resistance when the secondary receiving circuit contains a large inductance or a condenser.

This accounts for the even regulation curve shown by Mr. Lamme illustrating the regulation of the type S transformer operating on low power factor, and this is characteristic of any type of transformer (multiple) operating under the same conditions.

With regard to the operation of the meter on 25-cycles refer to Fig. 3.

Let $O\,E$ = Impressed e.m.f.
$O\,C$ = Current non-inductive.
$O\,C'$ = Current inductive.

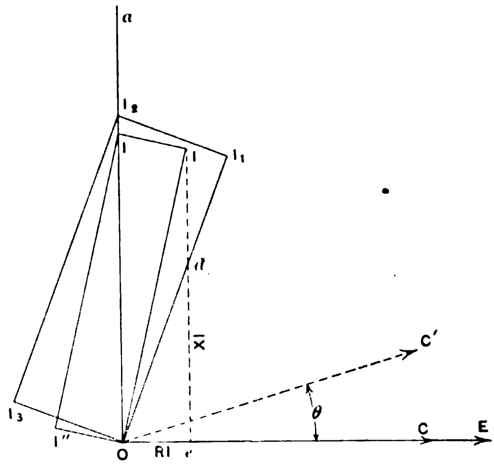


FIG. 3

$O\,I$ = Current in potential circuit.
$O\,I''$ = Current in lagging coil.
$O\,I'$ = Resultant current effect in potential circuit.

From the above it is at once evident that with a lowering frequency the impedance of both the potential and lagging windings will be decreased and the current flow, therefore, increased, thus increasing $O\,I'$, causing the meter to run fast.

In addition to this it is also evident that with the decreased frequency the reactance factor of the potential circuit, *i. e.* $X\,I'$ will be decreased 5/12, *i. e.* 25/60, making $X\,I$ equal to $d\,e$ instead of $I\,E$. This will bring the angle of lag of the potential winding to $O\,I_1$ making it necessary, therefore, to add an increased effect on the lagging coil to bring the resultant effect back to I_2 as the recorded power of the meter is equal to $O\,C \times O\,E \cos O$, and if the meter is not corrected it is therefore evident that with

OI' increased and an error introduced equal to IOI_1, the correction factor would be cos $IOI_1 + OI_2 — OI'$. In commercial service a pertinent example is noted in meters designed for operation on both 140 and 60 cycle circuits, which are double lagged, one coil being left open circuited on 140 cycles but short circuited through resistance when operating on 60 cycles.

From the above, therefore, three points are evident:

A. A lower trequency will reduce the error of phase displacement in a transformer except wherein a unity power factor condition exists in the transformer winding. In this latter case there will be no change.

B. The regulation of transformers is vitally dependent upon resistance of its windings and its relative regulation is not affected as greatly on low power factor as in comparison with high power factors.

C. Integrating meters operating on lower periodicities than that for which they are designed will run fast and the effect of a lower frequency on the primary transformer for such a meter will be cumulative with that of the meter itself.

S. G. Gassaway: I was somewhat agreeably surprised with the paper tonight as the gentleman did not include a lot of difficult mathematical formulae, which we expect to get from one coming from the University. The speaker tonight mentioned the V and Scott connections. The power factor of the V connections is 86.6, this has another meaning if you will consider it. It means that if the load has a power factor of 100 per cent the power factor in these transformers is 86.6. In other words, you have approximately 15 per cent greater transformer capacity than the capacity of the load connected. In the T connection we have a power factor of 92.8 per cent. In other words, you have something like 8 per cent more kilowatt transformer capacity than you have load connected.

The regulation of a transformer is really a sort of measure of the care with which it is constructed. A more carefully constructed transformer has better regulation. Regulation is important in the transformer that is being used for lighting, because the candle power of the lamps varies with the potential. In converter work, regulation is not so important because it can be taken care of by series reactive coils which allow for line drop, etc. and thus you obtain any regulation desired. Likewise with motor generators the regulation of the transformers is not important.

Regulation depends on a number of factors, one of which is the reactance or impedance of the transformer. If the transformer is not carefully constructed, and there is considerable flux leakage, that means the impedance is higher; in other words, poor regulation.

In the smaller sizes of transformers, we find the transformer is generally of the core type, because it is cheaper to make and it is lighter, but it has not in general as good regulation as a transformer of the shell type. The reason for this is obvious, because

in the shell type transformers there is a better opportunity for interlacing the coils thus preventing magnetic leakage. There are other reasons for using the shell type, especially in larger transformers, than that of regulation alone. In the shell type the coils can be arranged more advantageously for cooling and thus prevent hot spots which would be likely to occur were the very large capacity transformers made in the core type. It is possible to brace the coils more securely in the shell type, repairs are more readily made, and there are many other features which make the shell type desirable in large capacities.

Some of the first transformers that were designed had very poor regulation notwithstanding the care taken in designing them, and on investigation the cause was found to lie in the large eddy current loss in the casing due to the case being located too close to the core, thus causing a large flux leakage. On experimenting it was found that there would be little or no loss in the case if it were not located closer than three inches to the core.

The impedance of the transformer varies greatly with the spacing or arrangement of the coils. Some experiments were made on the core type of transformer on varying impedance, and it was found that impedance could be varied from 2.4 per cent to 150 per cent by spacing the coils. We found that when we had all the primary coils on one leg and all the secondary coils on the other leg of the transformer coil, the impedance increased until we reached as high a figure as 150 per cent, depending on the number of coils and how well those coils themselves were placed on the transformer.

The regulation of a transformer has another feature to be considered. We know the load divides itself amongst transformers in bank according to the relative admittance, I believe it is called, which is commonly taken as the kilowatt capacity divided by the impedance volts or the percentage in impedance volts. As I said, the regulation depends on the impedance; therefore, if the impedance is large, the regulation is poor, the relative admittance would be small, and we find that the transformer does not take its proper share of the load if it is connected with transformers that have better regulation.

C. L. Cory: I am very much interested in the paper this evening because it has given us an opportunity to understand the regulation of the transformer in a much broader sense than we do ordinarily. Summing up what has been said by the different speakers this evening it may be said that the regulation of a transformer, except as regards the change of the load, depends upon the resistance and reactance, and, by the way, reactance does not always mean inductive reactance, but it may mean condenser reactance as well. The regulation of a transformer, again depends upon leakage. An ideal transformer would be one in which the primary turn and each secondary turn occupy exactly the same physical space.

The paper this evening has interested all of us because it takes up the transformer from two different points; one, the

transformer which is used for meter purposes, that is the potential transformer, and the other, the practical transformer, which Mr. Lamme has chosen to call, the unsymmetrical transformer.

A number of people in this room probably remember the series of tests made about two years ago where it was decidedly important to determine the accuracy of meters working not on 60 cycles, but on 50 cycles; where the current was to be 10,000 measured volts; where the power factor would vary between 100 per cent and 80 per cent and where the magnitude of energy was to be about 5,000 kilowatts.

The checking of meters was a simple matter, but the checking of potential transformers and series transformers was an entirely different matter, and inasmuch as in this particular case an error of about one-half or one per cent represented a loss or gain to the company of about $5,000, accuracy was of some consequence.

To get at the method of determining this phase relation of primary and secondary between transformers of one manufacture and one of different manufacture, they were sent to the bureau of standards, and these transformers were operated not exactly at 60 cycles, but at 50 cycles, 48 and 52 cycles, and were connected as per instructions at the bureau of standards with reference to a standard 150-volt 200-ampere indicating instrument, and also each transformer of its particular type to a 5-ampere wattmeter that was used to measure the power. When these results were turned over to the company having charge of the tests it was found that the capacity of potential transformers had a great deal to do with the regulation; in other words, it determined that while one transformer had a great deal of insulation the other one did not have so much.

I should say that it was exceedingly dangerous, and subject to a very great error, to use a transformer and meter which were designed for 60 cycles on a 25-cycle circuit. In the first place you are running a very great risk of burning out your potential transformer, but under any circumstances I doubt very much whether, unless you knew definitely the curve showing the relation of the phase angle and the power factor, you could ever tell whether your meter was reading fast or slow. I am not quite sure but that under some conditions the meter would read fast and under others it would read slow.

F. V. T. Lee: The trouble particularly in regard to two-phase and three-phase or T connection has been well known in the past, but I think this is probably the first time that a good many of us have had an opportunity of having somebody explain the true inwardness of the trouble. I remember one case that may be of interest where a plant was installed in the northern part of California, and for reasons of economy it was necessary to use three-phase transmission. It was desirable to take two-phase machines and connect them for three-phase with the T connection. For some reason it was necessary to use two-phase motors. Some strange results were obtained, and what really happened was exactly as illustrated by the authors this

evening. Unfortunately the winding of the generator did not allow for adjustment and the result was that special generators had to be built, which overcame the trouble, and when received from the factory the generator leads and the motor leads were all carefully tagged as to how they should be connected, so no mistake could be made.

Those days have gone by, but it is necessary to have papers of this character, so that those who have not given it special attention will look out for it, and those who have met the trouble will see the solution. These academic papers really should not be stigmatized as being academic, for the reason that they come from the University where they have the time and opportunity to give these problems theoretical treatment, which those in practice haven't time to do.

G. C. Holberton: Apparently the discussion of the paper has shown us that there are errors of regulation. The author referred to regulation of power transformers, or lighting transformers such as we are using in practice, and that particular regulation is a matter that we can watch and if it is a very serious thing we notice it, but in the matter of transformers used for meters we cannot. I think for that reason we should go into it even further than has been gone into tonight. In the discussion tonight, as I take it, it has been brought out that there are errors, all of which are over one per cent. If these errors are cumulative we may have an error of several per cent, which I am safe in stating we cannot determine in the ordinary way. If we have two or three different kinds of errors, any one of which amounts to over one per cent, we are getting into very serious condition. It is no uncommon thing in the present state of or business to have bills running about fifteen or twenty thousand dollars monthly. When there is an error of two or three per cent, it is a very serious matter. I don't think the ordinary meter tester is capable of making an accurate test involving the current transformer and the potential transformer. The apparatus would be too bulky to carry around. I think it is necessary for some one to take up the subject from a practical standpoint and make these tests, which have been made at laboratory– make them under practical conditions.

W. A. Hillebrand: I have only one thing to say, and that is with reference to Mr. Lamme's remark about the effect of the power factor on the capacity of the converter, especially in the heating of the coils near the point at which the tap is brought out. Mr. Charters and I spent about three months last year investigating the behavior of induction and synchronous motors under various conditions. These were small machines, to be sure, not over 10 h.p. at most, but they showed the power factor to be extremely sensitive to even slight variations in either amount or phase relation of the applied electromotive forces; much more sensitive than might be expected from the inconsiderable current unbalance that occurs under these conditions.

Abstract of an address before the Ithaca Section of the American Institute of Electrical Engineers, January 21, 1910.

(*Subject to final revision for the Transactions.*)

LIGHTNING PROTECTION

BY PERCY H. THOMAS

It may seem strange that the subject of lightning protection for transmission lines is receiving so much attention on the part of electrical engineers, since lightning protective devices have nothing whatever to do with the ordinary operating characteristics of a transmission system. However, the reliability of a line is often dependent upon its adequate protection from lightning-discharges and in some sections of the country satisfactory service would be out of the question without such protection.

The origin of lightning seems still to be a matter of much conjecture. A possible explantion is that the clouds become strongly charged positively during storms, as a result of the ionization of the atmosphere by the sun's rays. Particles of moisture collecting about the negative electrons carry them down in their fall; thus increasing the electrical tension in the space between the separated electrons. This effect is illustrated in the familiar experiment in which the plates of a condenser are charged by the application of a moderate potential, and then separated some distance apart. The potential between the two charged bodies greatly increases, due to the greater distance of dielectric through which the given constant electrostatic field is maintained. During storms moisture collects also about the positively charged electrons, and they tend to follow the others. The earth is hot compared with the upper strata, and heated air tends to rise, with the result that cloud masses of great difference in electrical potential are brought nearer each other and electrical discharges take place; and further great upheavals or overturnings of air, the hot lying below the cold, cause the well-known cold gusts and showers of a thunderstorm. These

heavy charges in the atmosphere and the succeeding discharges affect all conducting bodies in the neighborhood. The effects are as follows:

(1) The slow approach of positively charged masses to a line tends to draw a bound charge into the line, which charge leaks slowly on to the wires over the insulators. This bound charge is maintained at practically the potential of the charged earth beneath. This effect is illustrated in Fig. 1.

If a discharge to earth occurs, the bound condition no longer exists, and the potential of the line is immediately raised as by a second charged body being suddenly removed to an infinite distance. The high potential of the line must be equalized in some way and a discharge occurs, either over the insulators or through apparatus, to the earth.

(2) Lightning discharge passing from one charge body to another induces high electromotive-forces in transmission lines

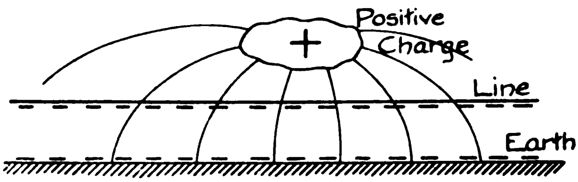


FIG. 1

just as e. m. f. is induced in the secondary windings of a transformer.

(3) Lines may become highly charged by direct stroke of the lightning. This actual discharge may take the form of heavy visible discharges or of silent discharges of more mild and of more frequent occurrence. These discharges cause local effects which usually result in a puncturing or an arcing-over at the insulators. The majority of these lightning disturbances are harmless when not reaching the line, and pass unnoticed.

They remind one of electrostatic experiments with spheres or long cylinders, representing the transmission line, and with electrostatic charges being constantly given to the charged body, adding to the charge already upon it. In fact, by lightning effects is understood any sort of disturbances of the nature of those occurring in electrostatic apparatus. For instance, if a 100,000-volt line accidently comes in contact with a low tension system a disturbance closely resembling a lightning

stroke occurs. A sudden rise of potential will accompany the redistribution of charges on the system. Such disturbances are even caused by short-circuits, synchronous motors falling out of step and similar occurrences which cause a disturbance of the electrostatic and electromagnetic field about the conductors of the transmission line.

In a transmission line the inductance and capacity of the system is distributed along its length as indicated in Fig. 2. A

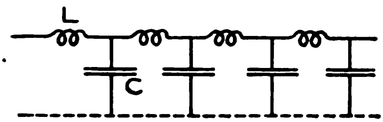


FIG. 2

transfer of energy from one end to the other, as when lightning discharges occur cannot take place instantaneously. A charge in passing along charges one condenser, is opposed by the next choke coil; later the second condenser reaches its maximum potential and so on, the current passing as a wave, which moves along until it reaches the far end. This resembles a wave of water in a long trough, which is reflected upon reaching the end and retraces its course, gradually losing force as its energy is dissipated in friction. A disturbance passing along a line per-

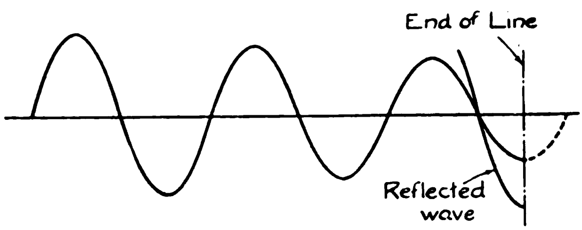


FIG. 3

haps maintains its shape from end to end. If upon reaching the end of the line, it encounters an open circuit, the wave is reflected and follows the line back, which process may continue until the energy is entirely dissipated. If the wave of potential is at its crest at the open end of the line, the reflected wave has twice the value of the oncoming wave, due to the superposition upon it of the reflected wave. This is illustrated in Fig. 3.

The magnitude of such disturbances is limited by the wave length of the disturbance. A mile-long wave cannot support a

great amount of energy, due to the limited capacity and inductance of this length of line. As the disturbances are of high frequency the wave length cannot be very long. Sufficiently high potentials are frequently generated to puncture or arc over the insulators.

Effects of Lightning. A direct stroke of lightning passes to earth within a few poles of the point struck, usually shattering the poles through which it passes to earth. Insulators are punctured or broken by such discharges.

Lightning disturbances often cause break-down of insulation in transformers and short-circuiting of the coils. This is explained by the fact that the high frequency disturbance upon meeting the high inductance of the transformer winding, induces such excessive potentials that an arc occurs through the insulation of the coils, which arc is often followed by the power-current of the generator and a short-circuit results.

Preventive or Protective Devices. In devising protective apparatus, two portions of the system must be considered separately

1. The line—exposed through its entire length.
2. The station—exposed only to waves coming in on the line.

Lightning will not pass far to go to the ground; therefore, to protect a line, lightning-arresters would have to be placed at frequent intervals. It is impossible to supply them as frequently as is ideally desirable, and yet a suspension of the service at any time is greatly objectionable. In some classes of service, particularly, a short interruption of service may be attended by serious results, as in the cases of pumps, keeping mines clear of water, or of fans supplying air to blast furnaces, where a stoppage of draft may mean a solidfying of the charge and necessity for dismantling the entire furnace.

(*a*) *Grounded Wires.* One means of protecting the lines is to mount a grounded wire above the wires of the transmission line, as shown in Fig. 4. While this affords some protection, the charge often jumps to the transmission line in what is called a "side flash." That the grounded wire does not afford a sufficiently easy path for the disturbance to reach the earth is evidenced by the fact that in one case the discharge punctured a 30,000-volt insulator, rather than pass to a ground provided at only one pole distance. Two ground-wires placed over a system afford better protection than one, as the charges do not usually come vertically but are swept along from the side, resulting in the discharge passing into one of the working conductors, rather than into the solitary ground-wire above.

The main objections raised against the ground-wires are:

1. Often the wires are not put up strongly enough and become loosened, with the result that they come in contact with the line conductors, causing a shut-down which is the very thing they were supposed to prevent.

2. A cost of several hundred dollars per mile is necessary if

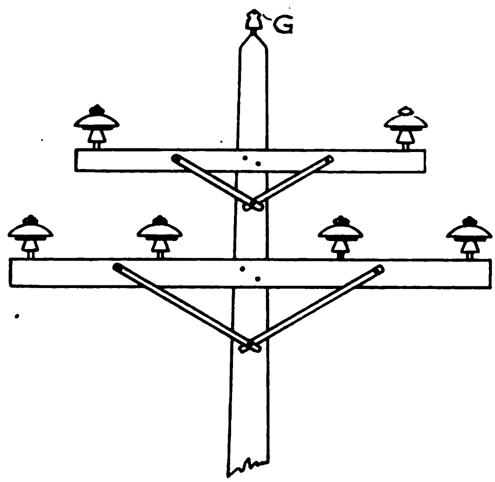


FIG. 4

suitable grounded wires be installed. In view of their lack of reliability, managers are unwilling to put the necessary money into them.

(*b*) *Spark-Gaps.* For the protection of apparatus against grounding, the simple device of an air-gap connected between the line and the ground at a choke-coil (Fig. 5) affords satis-

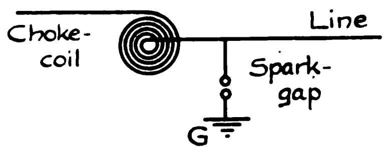


FIG. 5

factory protection in the case of such lines as telegraph lines. Where the power transmitted is considerable, this is not sufficient on account of the liability of the arc to continue and constitute a short-circuit on the system.

(*c*) *Lightning-Arresters.* Much money and thought have been expended in developing a suitable lightning arrester and new

types have recently been developed which seem superior to earlier types. As the energy capacity of the prime mover is increased, it becomes increasingly difficult to devise protectors which will allow the lightning discharge to take place and which will prevent the power-arc following. This has been attempted in several ways. First, means were devised to draw out the arc, and thus rupture it after the high-tension discharge had passed. This brought relief to low-capacity systems only.

The magnetic blowout was devised and is still largely utilized on low-tension and direct-current systems. Here the short-circuit current in flowing through the coils of an electromagnet suitably placed with regard to the spark-gap, produces a magnetic field in which the arc is drawn out and ruptured.

A further improvement was introduced by Wurtz, who used a

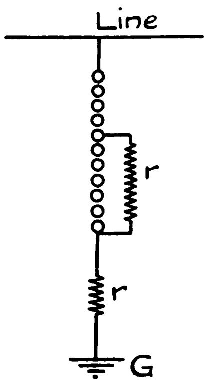


Fig. 6

multiple spark-gap consisting of several cylinders of non-arcing (zinc-brass) metal. This is satisfactory for systems using comparatively low powers only. Its utility has been enhanced by the insertion of resistances in parallel with the portion of the multiple gap, as shown in Fig. 6. This allows the passage of the high-potential discharge, while somewhat limiting it, but the resistance reduces the power-arc and it is ruptured by the non-arcing gaps.

The type of arrester which promises most for high-tension, high-power systems is, the electrolytic arrester. In principle it is ideal and in application it is simple. It provides a shunt path to the ground through which the normal current cannot pass, while static charges find a fairly easy issue, after which the normal high resistance is returned.

The principle of the electrolytic arrester is as follows: If two aluminum plates be immersed in a suitable alkaline solution and subjected to a difference of potential, a momentary deposition of an hydroxide of aluminum takes place on the cathode, establishing a very high resistance to the further flow of current. Such a film has a puncture voltage of about 400 volts. If the potential is reversed, current flows and dissolves the thin film previously formed and deposits a new film on that plate which is now the cathode. Such a cell if connected between the line-wire and the ground prohibits by its resistance the flow of current at the normal voltage of the line (if less than 400) but allows higher potential currents of lightning phenomena to pass unhindered, after which the insulating film is re-established. In order to make such an arrester applicable to high potential lines a number of such cells must be connected in series. This is ordinarily

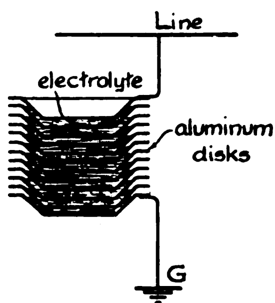


FIG. 7

done by placing one dish-shaped plate within another (Fig. 7.) each dish being filled with the electrolyte and the whole placed in a jar, which may be cooled and insulated by oil. While superior to earlier types such arresters have several weak points.

The electrolyte must be very pure, or the film will be easily punctured.

The arrester must be kept cool.

The arrester must be put up level to prevent the flow of electrolyte over the edges of the plates.

The electrolyte must not freeze, because while frozen it will not operate.

It is difficult to insulate the series of plates at the edges.

In spite of these objections this type of arrester promises to be the best arrester so far developed for high-potential systems.

Protection of Apparatus. Well-insulated choke coils are in-

serted in lines to receive the static wave and divert it to arresters. Transformers are now built with such adequate insulation that they are not liable to be punctured. The winding is so designed that adjacent conductors in the same layer are subject to but slight differences in potential, while consecutive layers of conductors are heavily insulated from each other.

Choke coils in the leads of generators tend to limit the current established on short circuit. This simple device has proven of great assistance in limiting the damage of short-circuits in the generating station of the New York, New Haven and Hartford Railroad.

While it is possible to design transformers so that they will stand a tremendous increase in potential, the same is not true to a great extent in electric generators, as there the nature of the windings, with sharp bends, proximity of conductors of very different potential, and the impossibility of using oil for insulation, conspire to make the problem a more difficult one, so that alternators are rarely built for potentials above 10,000 or 15,000 volts.

Caution should be used in installing instruments requiring series transformers, as these transformers act as choke coils to the wave of disturbance, and their insulation is often punctured. resulting in grounds, serious in that they endanger the lives of employes and lead to the burning out of meter coils and to other damage to apparatus. A spark-gap is sometimes put around such coils to allow the over-potential to discharge around the instruments. These coils being in series with the line are not subject to the generator potential between terminals, and the generator current does not, in general, follow the arc so established.

In the application of lightning arresters to outdoor distributing circuits, as in lighting circuits in municipalities where transformers are widely scattered on the lines, account must be taken of the fact that serious disturbances do not follow the line for any great distance, but pass to the ground within a few poles of the occurrence of the disturbance. It is therefore necessary, theoretically, to install a great many arresters. As a compromise, only as many arresters are installed as are found by practice to be necessary to maintain a fair reliability of service. The place of arresters is often taken by trees which are close to the wires and transformers, so that in cities a great many arresters may be dispensed with.

A paper presented before the Philadelphia Section of the American Institute of Electrical Engineers, on January 10, 1910.

THE 1200-VOLT RAILROAD—A STUDY OF ITS VALUE FOR INTERURBAN RAILWAYS

BY CHARLES E. EVELETH

The various 1200-volt interurban railways have now been operating a sufficient length of time to prove that there are no material objections to the use of this voltage on passenger cars. The nature of such minor difficulties as have been experienced have been such that their correction has required only detail changes of design which have been readily made. The important items of reliability and low cost of upkeep have met all expectations.

A single statement regarding the motors may explain the reason for this successful performance. On the Pittsburg, Harmony, Butler & Newcastle line where the service is unusually severe on account of unusual grades and curves, a considerable number of the brushes originally shipped in the motor brush holders are still in service, though many motors have now run over 150,000 car miles, and the wear on the commutators is hardly perceptible. It can be stated from the performance of the 1200-volt system that nothing is jeopardized by the adoption of this system, and such economies as are possible by its use can generally be obtained without offsetting disadvantages.

We may therefore assume that the 1200-volt system has "found itself" and a new system is thereby made available for consideration when studying the requirements of new railroads or extensions to existing systems. If desired, the cars may be run at equal efficiency over tracks equipped for 600 volts.

This being the case, the question naturally arises, what gains may be expected from the use of this higher voltage?

The primary object of any railway is to pay dividends and these are limited by the amount of receipts which must be expended for two items,—fixed charges, and operation. The most inflexible item is fixed charges. This works twenty-four hours a day whether business is good or bad and never gives up any ground once gained. Its only vulnerable point is the first cost of the railway. The 1200-volt system now offers a practical way of reducing the first cost of electrification through the material saving in substations and secondary distribution conductors. This gain becomes a permanent asset of the railroad, making

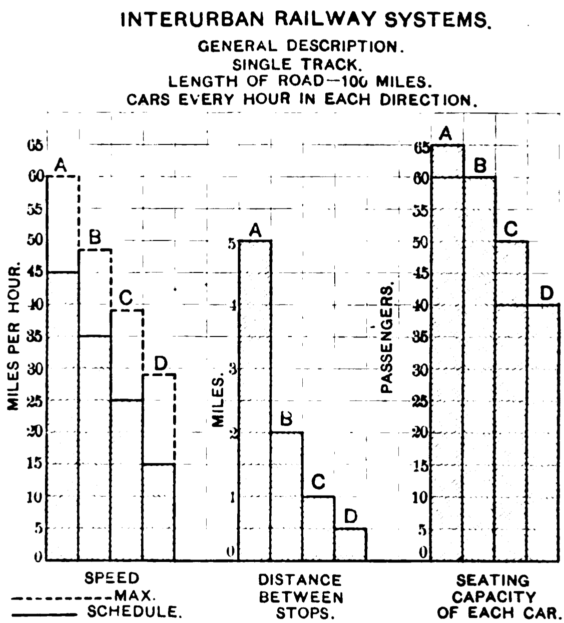


FIG. 1

a definite decrease in the fixed charges at a place which cannot be reached in any way except by raising the voltage.

The other item is cost of operation. This item may be controlled to a certain extent by the personal ability of the manager, but having once selected the type and size of cars and the voltage of the system it is practically impossible for him to materially change the cost of getting power to his cars, which depends upon the distribution efficiency of his system and the cost of substation operation. The 1200-volt system decreases the cost of getting power to the cars in two ways; first, reducing the number

of substations, and second, increasing the substation efficiency by improving the load factor. This latter result may seem unreasonable at first thought until one considers upon what grounds substation units are selected. They are not selected on the basis of heating, for it is probable that there are few interurban stations in this country running with 50 per cent average load factor, and the average is certainly below 30 per cent for the ordinary interurban conditions. It is generally necessary for the station unit to commutate within its overload guarantees, the maximum starting current of at least two trains starting simultaneously. As the running current of a train is about one third of the starting current, and there are considerable periods during coasting and stops when the train is taking no current, and, furthermore, there are generally times when no trains are on the section fed by an individual substation, the low load factor can readily be accounted for. If then the units are selected for peak conditions the capacity of each station will remain constant independent of the number of stations. It is evident when decreasing the number of substations, that is, increasing the track mileage fed by each station, that the average load will be greater and the substation load factor and efficiency improved. The total substation cost and operation will be decreased practically in proportion to the reduction in the number of stations. These advantages are net advantages since they are, in the 1200-volt system, obtained without being offset by extraordinary car equipment maintenance.

Any railway is complex, but there are certain fundamental differences, namely track mileage, size of trains units, and schedule speeds, which have a definite influence on the cost of electrification. In order to obtain an idea of the advantages which may be expected with the use of 1200 volts as contrasted with 600 volts, let us consider some concrete applications to different classes of conditions from which we may be able to draw some general conclusions.

DESCRIPTION OF RAILROADS

	A.	B.	C.	D.
Length of road, miles, all single track	100	100	100	100
Time between trains each direction, minutes	60	60	60	60
Cars per train	3	1	1	1
Seating capacity per car	65	60	50	40
Distance between stops, miles	5	2	1	0.5
Schedule speed, miles per hour	45	35	25	15
Maximum speeds, miles per hour	60	48	38	28
Car-miles per day	9000	3000	3000	3000

In making these comparisons conservative values have been used, such as low substation costs, high cost of 1200-volt car maintenance, etc. so that the results will be conservative and the advantage rather less than might actually be achieved.

It will be seen that the roads vary greatly in conditions, from the heavy railroad conditions of *A*, through heavy interurban *B*, light interurban *C*, and very light traffic *D*. In fact, the cars of *D* will be no heavier than many city cars. See also Fig. 1.

Cars. Based upon the requirements, the following data may be considered reasonable for the cars.

CARS
GENERAL DATA

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Number	60	60	15	15	17	17	20	20
Cost each	$15,000	$13,000	$11,000	$10,000	$8,000	$7,000	$5,000	$4 500
Weight, tons	46.5	45	36	35	27	26	18	17
Amperes, starting	900	1650	140	260	100	185	60	110
" running	100	187	47	87	33	62	20	37
Kw-hr. per train mile	11.16	10.8	2.88	2.80	1.89	1.82	1.08	1.02
Car-miles per day per car	150	150	200	200	176	176	150	150

It will be noticed that the power consumption which is "at the train" is slightly more for the 1200-volt cars on account of the greater weight of their equipments.

CARS
COST OF MAINTENANCE
Cents Per Car Mile

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Mechanical	1.25	1.25	1.00	1.00	.90	.90	.75	.75
Electrical	.99	.90	.77	.70	.60	.55	.55	.50
Total	2.24	2.15	1.77	1.70	1.50	1.45	1.30	1.25
Yearly cost	$73,500	$70,500	$19,400	$18,600	$16,400	$17,000	$14,300	$13,700

In this estimate, 10 per cent greater maintenance is allowed for the up-keep of the 1200-volt electrical equipment. As a matter of fact up to the present time no noticeable increase has been observed.

Substations. In selecting the size of synchronous converter units for the stations they are in this case based on a maximum

momentary demand of two cars starting simultaneously, except in the case of system *A* where the size is based on the demand of one train starting and one train running. In each case a reasonable margin is allowed for occasional additional service.

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Number of substations......	6	14	4	9	3	6	3	5
Est. momentary demand, kw...	1,440	1,320	336	312	280	222	192	154
Number of units........	2	2	2	2	2	2	2	2
Size of each unit........	1,000	1,000	300	300	200	200	150	150
Cost of station, each...	$60,000	$56,000	$26,400	$24,000	$20,200	$18,400	$17,100	$15,600

The number of substations is dependent upon the maximum economical spacing, considered in conjunction with the cost of feeder copper and the allowable line drop with the assumed conditions of load. In each case it will be found that the addition of another substation to the number given in the data will not save its equivalent in cost of feeder copper. This brings up the question as to what may be considered equivalent feeder copper. The table below gives these equivalents.

EQUIVALANT FEEDER COPPER TO REPLACE ONE SUBSTATION

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Annual cost of labor and material........	$2,500	$2,500	$1,900	$1,900	$1,800	$1,800	$1,700	$1,700
Fixed charges........								
Interest........ 5%								
Depreciation.... 3%								
Taxes and insurance......... 3%								
Total........11%	6,600	6,160	2,904	2 640	2,222	2,024	1,881	1,716
Total....	$9,100	8,760	4,804	4,540	4,022	3,824	3,581	3.416
For feeder copper the interest, etc., will be approx. 8½ per cent								
Investment in feeder copper equivalent to each substa. will be..	$110,000	106,000	$58,300	$55,000	$38,800	$46,400	$42,400	$41,400

The acutal amount should be somewhat greater than these values, for with the addition of a substation there is a reduction in load factor on each substation, lowering the distribution efficiency. A curve is given, Fig. 2, to show the change in substation efficiency with change in the load factor on individual synchronous converters. This curve is for a station having 150-kw. to 300-kw. units. For the larger machines the curve would be about two per cent higher.

It will be seen that the investment in feeder copper which

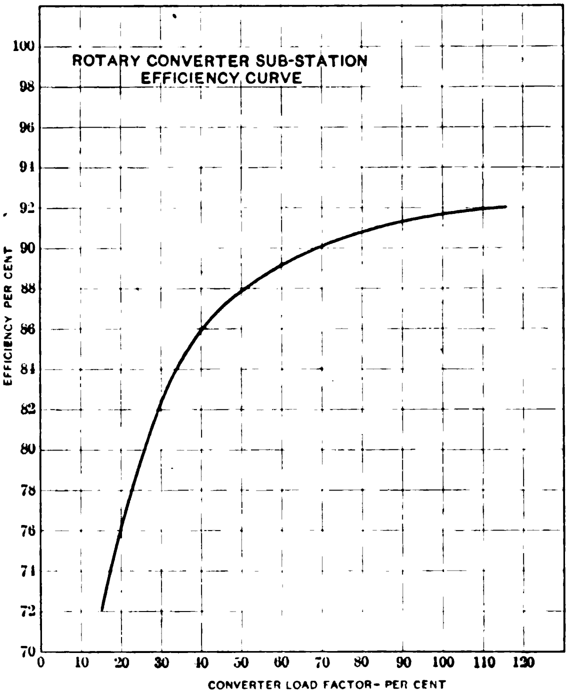


FIG. 2

must be saved to justify an additional substation will be approximately $2\frac{1}{2}$ times the cost of the substation.

An examination of the diagram, Fig. 3, showing the "location of substations" will give a fairly comprehensive view of the railroad lay out and the location of the cars at any hour.

Primary Distribution. This in each case will be the same for either system, except that the total length of the 600-volt transmission line will be slightly longer on account of the greater distance between the terminal stations. A flat price of $3,500

per mile of transmission line is taken for system *A*, and $1,000 per mile for system *B*, *C*, and *D*.

It will make practically no difference where the power is fed to the high tension system. For the sake of simplicity it is assumed that power is purchased and delivered to the power house step-up transformers at one cent per kw-hr.

Secondary Distribution. Track. For railroad *A*, 85-lb. rail is assumed. This has a resistance per mile, including bonding,

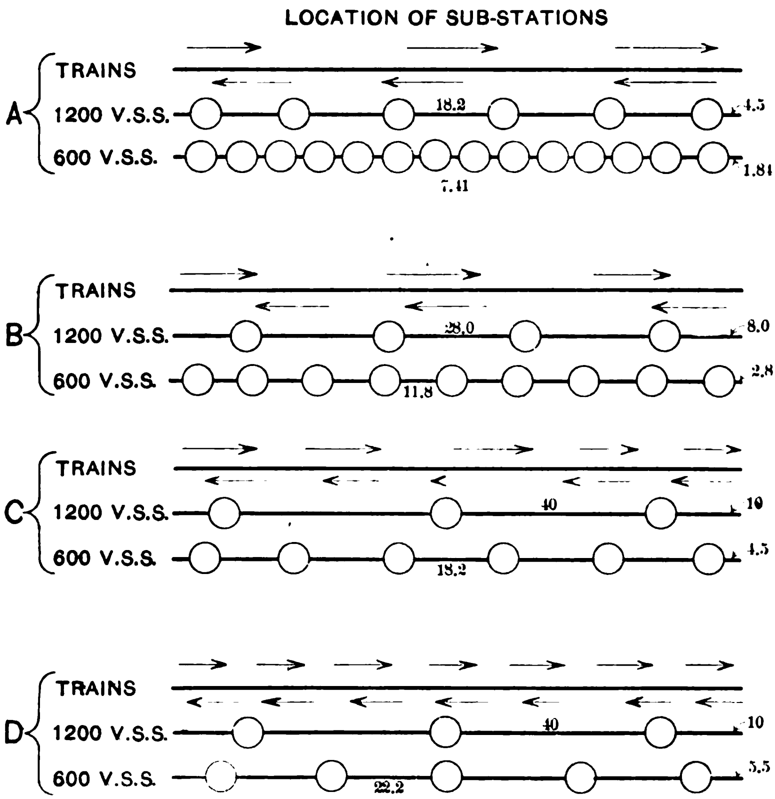


Fig. 3

of approximately 0.033 ohm. The other roads use 70-lb. rail having a resistance per mile of 0.04 ohm. A third-rail equivalent to a 1,000,000-cir-mil. feeder is assumed for *A*, and No. 0000 trolley wire for the other roads. The values used in obtaining the feeder copper necessary are based on a maximum drop of 250 volts for the 600-volt systems and 500 volts for the 1200-volt systems. This will give an average secondary distribution efficiency of approximately 90 per cent.

FEEDER COPPER REQUIREMENTS

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Stub End Calculations:								
Trains starting and running...........	1S–1R	1S–1R	2S–1R	2S	2S–1R	2S	2S	2S
Total current, amperes	1200	2200	327	520	233	370	140	220
Length stub end miles,	4.5	1.85	8	28	10	45	10	5.5
Size copper required..	None	1,000,000	No. 000	No. 0000	No. 00	300,000	No. 0	No. 00
Between Substations:								
Trains starting and running...........	1S–1R	1S–1R	2S–2R	2S	2S–2R	2S	2S–2R	2S
Amperes............	1200	2200	374	520	266	370	160	220
Dist. between substations, miles........	18.2	7.41	2.8	11.8	40	18.2	40	22.2
Size copper required..	None	1,000,000	No. 0	No. 0000	No. 00	300,000	No. 0	No. 00
Total cost of feeder installed..............		290,000	53,200	80,000	60,000	100,000	50,000	60,000

FEEDER COPPER—COST PER MILE INSTALLED

Size...............	No. 0	No. 00	No. 000	No. 0000	300,000	1,000,000
Cost...............	$500	$600	$700	$800	$1,000	$2,900

For track bonding $450 per mile has been taken for *A* and $400 per mile for *B*, *C* and *D*.

POWER CONSUMPTION

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Kw-hr. per day at cars.............	$33,500	$32,400	$8,640	$8,400	$5,670	$5,470	$3,240	$3,060
Converter load factor	0.31	0.13	0.44	0.19	0.58	0.28	0.45	0.25
Efficiency (average)								
Substation.........	0.836	0.69	0.87	0.76	0.89	0.823	0.873	0.803
Secondary distribution............	0.90	0.90	1.90	0.90	0.90	0.90	0.90	0.90
Transmission......	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Step-up transformers.............	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97
Combined.........	0.722	0.595	0.745	0.632	0.761	0.705	0.748	0.688
Kw-hr. per day purchased).........	46,500	54,500	11,600	13,300	7,450	7,750	4,330	4,440
Cost per year at one cent per kw-hr...	$169,000	$199,000	$42,400	$48,600	$27,200	$28,200	$15,800	$16,200

SUMMARY OF COSTS
ELECTRIFICATION MATERIAL

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Cars	$960,000	$840,000	$172,500	$150,000	$136,000	$119,000	$100,000	$90,000
Substations	360,000	784,000	106,000	216,000	61,000	110,000	51,000	78,000
Transmission	318,000	340,000	84,000	94,000	80,000	91,000	80,000	88,000
Trolley*	625,000	600,000	160,000	160,000	160,000	150,000	160,000	150,000
Feeder	None	300,000	53,000	80,000	60,000	100,000	50,000	60,000
Bonding	43,000	43,000	40,000	40,000	40,000	40,000	40,000	40,000
	2,308,000	2,909,000	615,500	730,000	537,000	610,000	481,000	506,000
Track, roadway, etc	2,500,000	2,500,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Total	$4,808,000	$5,409,000	$2,415,500	$2,530,000	$2,337,000	$2,410,000	$2,281,000	$2,506,000
Note: Substation buildings	45,000	105,000	20,000	45,000	14,000	29,000	14,000	23,000
Substation electric equipment	315,000	679,000	86,000	171,000	47,000	81,000	37,000	55,000
Cars and substations	1,320,000	1,624,000	278,500	386,000	197,000	229,000	151,000	69,000
Distribution materials	998,000	1,285,000	337,000	364,000	340,000	381,000	330,000	338,000

* Third rail used on *A*.

FIXED CHARGES
ELECTRIFICATION MATERIAL

	Life years	Annuity 5 per cent	A 1200 volt	A 600 volt	B 1200 volt	B 600 volt	C 1200 volt	C 600 volt	D 1200 volt	D 600 volt
Depreciation										
Cars	15	46.34	$44,500	$39,000	$8,000	$7,000	$6,300	$5,500	$4,600	$4,200
Substation buildings	30	15.05	700	1,600	300	700	200	400	200	300
Substation apparatus	20	30.24	9,500	20,500	2,600	5,200	1,400	2,400	1,100	1,700
Transmission	20	30.24	9,600	10,300	2,500	2,800	2,400	2,700	2,400	2,700
Trolley	12	*62.83	18,900	18,100	10,100	9,400	10,100	9,400	10,100	9,400
Feeders	20	30.24	—	9,100	1,600	2,400	1,800	3,000	1,500	1,800
Bonding	10	79.50	3,600	3,600	3,200	3,200	3,200	3,200	3,200	3,200
			86,800	102,200	28,300	30,700	25,400	26,600	23,100	23,300
Interest: 5 per cent on total cost of electrification material			116,000	145,000	31,000	36,000	27,000	30,000	24,000	2,500
Taxes: 1½ per cent of total cost of electrification material			36,400	43,700	9,200	11,000	8,000	9,100	7,200	7,600
Insurance: 1½ per cent of cost of rolling stock and substations			19,800	24,200	4,200	5,500	2,000	3,400	2,200	2,500
Total fixed charges			259,000	315,100	72,700	83,200	62,400	69,100	56,500	58,400

* Third-rail depreciation based on 20 years life.

COST OF OPERATION AND MAINTENANCE

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
Transmission	$9,000	$9,500	$3,000	$3,300	$2,800	$3,200	$2,800	$3,100
Trolley and feeders	15,000	15,000	9,000	9,000	9,000	9,000	9,000	9,000
Rolling stock	73,500	70,500	19,500	18,500	16,500	17,000	14,500	15,000
Substations	15,000	35,000	7,600	17,000	5,500	11,000	5,000	8,500
Cost of power	169,000	199,000	42,400	48,600	27,200	28,200	15,800	16,200
	281,500	329,000	81,500	97,100	61,000	68,400	47,100	50,800
Total operation and maintenance of items listed	282,000	329,000	82,000	97,000	61,000	68,000	47,000	51,000
Statistics indicate that the items listed on 600-volt roads constitute approximately 44 per cent of the total operating cost. Based upon this there should be added to each of the above.	421,000	421,000	123,000	123,000	87,000	87,000	65,000	65,000
Total yearly cost of operation and maintenance of 3,285,000 car-miles per year for *A* and 1,095,000 car-miles per year for *B*, *C* and *D*	703,000	750,000	205,000	220,000	148,000	155,000	112,000	116,000

COMPARISON OF SYSTEMS

	A		B		C		D	
	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt	1200 volt	600 volt
I.—First Cost:								
Track, roadway, etc.	$2,500,000	$2,500,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000
Electrification material								
Car equipments	960,000	840,000	172,500	150,000	136,000	119,000	100,000	90,000
Substations	360,000	784,000	106,000	216,000	61,000	110,000	51,000	78,000
Distribution	988,000	1,285,000	337,000	364,000	340,000	381,000	330,000	338,000
Total	$4,808,000	$5,409,000	$2,415,500	$2,530,000	$2,337,000	$2,410,000	$2,281,000	$2,303,000
In favor of 1200 volts	—	601,000	—	114,500	—	73,000	—	26,000
II.—Fixed Charges:								
Track, roadway, etc., 7 per cent	175,000	175,000	126,000	126,000	126,000	126,000	126,000	126,000
Electrification material	259,000	315,000	73,000	83,000	62,000	69,000	56,500	58,500
Total	434,000	490,000	209,000	209,000	188,000	195,000	182,500	184,500
In favor of 1200 volts	—	56,000	—	10,000	—	7,000	—	2,000
III.—Operation and Maintenance:								
Miscellaneous	421,000	421,000	123,000	123,000	87,000	87,000	65,000	65,000
Electrical	282,000	329,000	82,000	97,000	61,000	68,000	47,000	31,000
Total	703,000	750,000	205,000	220,000	148,000	155,000	112,000	116,000
In favor of 1200 volts	—	47,000	—	15,000	—	7,000	—	4,000
IV.—Annual Cost II+ III	$1,137,000	1,240,000	414,000	429,000	336,000	350,000	294,500	300,500
In favor of 1200 volts	—	103,000	—	2,500	—	14,000	—	6,000
V.—Revenue:								
Additional receipts per car-mile necessary to pay additional cost of operation, etc., for 600 volts	—	3.1c.	—	2.28c.	—	1.28c.	—	0.55c.

NOTE.—3,285,000 car-miles per year for *A*.
1,095,000 car-miles per year for *B*, *C*, and *D*.

COMPARISON OF SYSTEMS

	600 volt per cent	A 1200 volt per cent	B 1200 volt per cent	C 1200 volt per cent	D 1200 volt per cent
I.—First Cost: All electrification material..........	100	79.4	85.5	88.0	95.0
II.—Fixed Charges: All electrification material..........	100	82.3	87.3	90.0	96.5
III.—Operation and Maintenance: All electrification material..........	100	85.8	84.5	89.9	92.0
IV.—Annual Cost II+ III: All electrification material..........	100	84.0	86.0	90.0	94.0

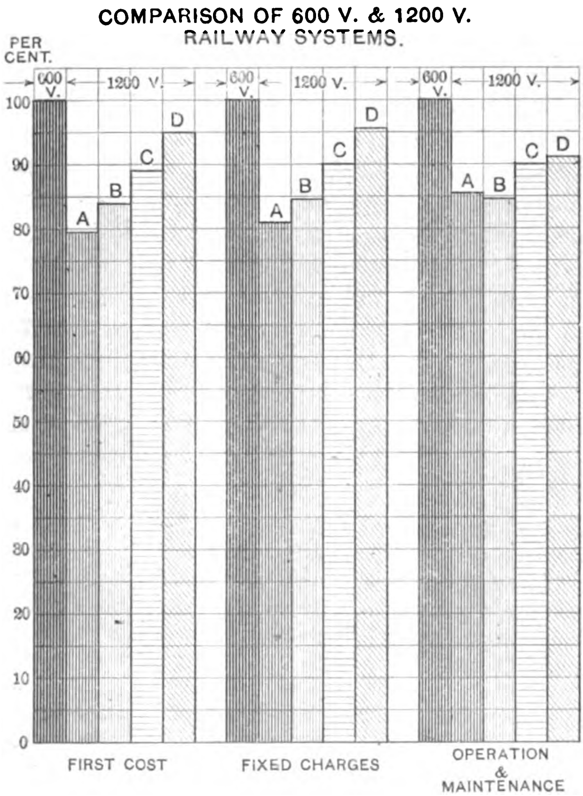


FIG. 4

In electrification material there is included under " first cost " and " fixed charges," (I and II) cars and car equipments, substations complete, transmission line, trolley or third rail, low tension feeders and track bonding.

Under " operation and maintenance " (III) of electrification material there is included rolling stock, substations, trolley, feeders and track bonding, and cost of power, *i. e.* all items which are affected by choice of system. Platform charges, general expenses, etc, common to both systems are not included.

On examination of these results, which are based on conservative figures on account of the relative newness of the 1200-volt system, it is apparent that the higher voltage effects economies at points that can only be reached by a change more fundamental than is possible with the lower voltage.

The saving of 1½ to 2 cents per car mile will permit a very material increase in dividends.

It is further clear that the relative value of the higher voltage increases as the demand for power increases, and that below a certain size of equipment there would be practically no justification for the adoption of the higher voltage. Results are shown for convenience in graphical form Fig. 4, as this indicates clearly how the economies change with the change in the system.

The place where the application of the 1200-volt system may be looked for in the immediate future is that field of interurban railroading where it has already made its successful start.

Conclusion. In conclusion it appears that a conservative estimate of the economy obtained by a 1200-volt system as compared with the 600-volt system in the elements of a railroad which are effected by the choice of system, that is, all of the electrification material, would place these savings approximately as follows:

1. First cost .... 10 to 20 per cent
2. Fixed charges .... 10 to 18 per cent
3. Operation and maintenance .... 10 to 15 per cent

Furthermore, experience has shown that

4. The 1200-volt system is just as reliable as the 600-volt system.
5. Substations may be operated from a system of any commercial frequency.
6. In specific cases the saving has been found materially greater than indicated in conclusions 1, 2 and 3, notably where the length of road is such that no substations are required for the 1200-volt system while substations are required for the 600-volt system. In some insatnces the savings have been as great as 25 or 30 per cent in the electrification material.

DISCUSSION ON "THE TWELVE HUNDRED-VOLT DIRECT-CURRENT RAILWAY SYSTEM." PHILADELPHIA, JANUARY 10, 1910

(Subject to final revision for the Transactions)

Mr. Murray: I want to speak of the New York New Haven and Hartford system, because in reviewing the paper tonight, I find that Mr. Eveleth has not mentioned, throughout all of his interesting lines, the single-phase system.

It is to be noted that the discussion is strictly direct current vs. direct current, and not direct current vs. alternating current. I believe there is a zone which is a function of traffic or distance, not the combination of both, but the one or the other, which requires the use of a system as brought out in Mr. Eveleth's paper.

I should have been very much interested, if, in the classification that Mr. Eveleth has used (A, B, C, and D), a third system, the single-phase, had been introduced for comparison.

I want to try to acquaint you with the conditions that exist on the New Haven road in comparison with the conditions cited. For example in A the heaviest conditions are used. Let us assume the cars weigh 60 tons apiece, or say 80 tons. Three of them will total between 180 and 240 tons for the train. Now with the New Haven, our trains run up to a maximum of 800 tons. Our minimum weight of trains is over the maximum A conditions.

I cannot pay too high a compliment to Mr. Eveleth for the earnest effort his paper indicates. I would like to say this, however, that I think it is slightly more academic than would be the case if he had actual field data from which to make the compilations. The 1200-volt system, of course, has not been sufficiently long in operation to afford comparison, but the framework and the synopsis of the whole scheme is so well arranged that the highest tribute is due Mr. Eveleth for the manner in which he has put it together; and in the future, when electrical engineers are collecting such data, I can think of no better arrangement than the one which Mr. Eveleth has laid before us.

One thing that struck me as important is the question of motor slip on the 1200-volt system. It is quite evident that eventually this system will include the 1200-volt motor itself, but it is the combination of the 600-volt motor and 1200-volt line that is included in the paper tonight. Thus, in the event of the motor slipping it does not eliminate the bad effect that would result in the collection of the full voltage across the terminals of the motor, and while low motor speed would take care of mechanical difficulties, the slip would inevitably lead to commutator flashovers of a serious nature.

Reference is made to the conditions of a 250-volt drop in a 500-volt line, or a 500-volt drop in a 1200-volt line. Some electrical engineer has paraphrased an old saying, which now reads: "It is voltage that makes the mare go." In order to find out the drop in the New Haven system during the rush

hours of the morning and afternoon, voltmeter readings were taken at Woodlawn, 18 miles from the power station. The voltage never fell below 9,800.

Another point in this paper is that the calculations are based on theoretical assumptions of trains taking current in the vicinity of substations. Upon the basis of this assumption many of the financial considerations of the paper are involved, and one can see in an instant that this is the crux of the whole situation. If I had attempted to write the paper, I should have made the same assumption. While it seems perfectly reasonable to make these assumptions, at the same time this brings out the academic feature to which I have referred, and emphasizes the fact that we lack the data of actual 1200-volt practice.

One point I want to make tonight, more than anything else, is that electricity can ceitainly wear a great many different suits of clothes. I think the 1200-volt system has come to stay, and that it is applicable to certain classes of interurban service. The first reason, to me, for its adaptability to these conditions is, that it does away with something that has been a nightmare to us, particularly on the New Haven road. In nearly every city there is and will be direct current. One of the earliest mistakes made with the single-phase was the attempt to combine it with direct current. I would like nothing more than to be able to eliminate direct current from our system. I think the best reasons for the existence of the 1200-volt system are the excellent opportunity it affords for the reduction or elimination of substations in rural territory, and the facility with which motors operating on lines of this voltage can be made to accommodate themselves to equally efficient operation on 600-volt city lines, bringing into sharp contrast the obnoxious arrangement of the combined alternating and direct current equipment.

Dr. Hutchinson has recently given us an interesting paper in which he has cited the true conditions for the application of a three-phase system. Just as the 1200-volt system will be applicable to interurban roads, conditions will likewise be met in another case, where the three-phase must step in as the preferred system. That system which figures the least first cost and operating expense must rule. That is one thing I think we ought to realize, namely, that, if we make a success of something, it does not necessarily follow that it applies to everything else.

Now I want to acquaint you a little more thoroughly with the New York, New Haven & Hartford conditions. First, it is a trunk line proposition; 60 miles of four-track road. This mileage covered the primary consideration, with its possible extension to Boston, the total distance of which would then be 220 miles. As I have stated before, our passenger train weights reach a maximum of 800 tons, and the service between New Haven and New York would require as many as 175 trains daily. On the freight side of the schedule, trains of 1500 tons are common

the average being in the neighborhood of 1200 tons, and as many as 80 of these trains are in daily operation between New Haven and New York. In reviewing these conditions it is clear that nothing under the classification of *A*, *B*, *C* and *D* even approximates them.

The history of alternating current shows that it has steadily replaced direct current wherever power and distance are involved. What greater field for the application of this agency exists, than an 800-ton Pullman train which may be seen standing in the Grand Central station, with sign boards marked "Boston." As an electrical engineer, is not your first mental conception of this train associated with power and distance?

One of the points in Mr. Eveleth's paper that has particularly interested me, is the gradual betterment in first cost and operating expenses by the use of a 1200-volt system in preference to the 600-volt, as it passes from the conditions imposed by city requirements to light interurban traffic, and finally to those conditions required in heavy interurban traffic. This suggests to me the system that comes into play after the 1200-volt system has done its best. It is fair to assume that 1200 volts on the direct-current motor will not be exceeded. Thus, with the motors in series it is possible to establish a 2400-volt line. This may widen the field of application of the 1200-volt system for interurban work, but its competition under trunk line conditions, such as obtain on the New Haven road, disappears when compared with single-phase current with 11,000 volts overhead. There is nothing to prevent a higher voltage than 11,000. It is not impossible to conceive of 22,000-volt transcontinental lines for the future. The increase of voltage by direct-current system is limited on account of the impossible condition imposed of increasing the voltage of the motor to an impracticable point, while in the case of the single-phase system the very antithesis of this condition holds, in that it is perfectly possible to raise the line voltage and reduce the motor voltage even lower than that at present used.

In connection with a single-phase system, I wish to say that I thoroughly believe its principal application is relegated to just one thing, trunk line traffic. I do not think, except for isolated branch or interurban lines that come within the zone of power supply from a trunk line system, that it is applicable to interurban or city lines, but I believe it is the only system today which can produce the economies that a railroad president and his board of directors would listen to, in the matter of steam road electrification.

Now a word as to why I believe this. One of the greatest and most unproductive mileages of steam lines in the eastern territory consists of yards, sidings and branch lines. In such territory as is involved by our Atlantic coast lines, let us say between Boston, and, for the present, Washington, think of the innumerable yards that must be electrified in order to handle

freight by electricity. The greatest economy can only be obtained by using high voltage power. Mr. Stillwell compiled some very interesting figures in regard to the efficiency of electricity for steam railroad traction. Using some twenty steam locomotives over a long period of test we have been able to corroborate these figures, and establish the ratio of 1 to 2, for coal burned in electric vs. steam traction, with the density of traffic, for instance, such as exists on the New Haven road. It is unquestionably true that if these large areas are to be electrified it will be impossible on a direct-current basis to put up a sufficient amount of copper to handle with proper economy the requirements in the yards for switch and road engine work. We must go to the high-voltage low-priced conductor. The use of the third-rail is prohibitive, for two reasons; first, it is dangerous; and second, the costs involved are on a lineal basis; that is to say, it may be feasible to lay down a main line third rail, but in the case of yards it fails in comparison with the economies that can be effected by the overhead conductor. The cost of the overhead system in yards has been reduced to about one half, or perhaps 35 per cent, of the cost of main line electrification, and in this way these large unproductive areas may be taken care of.

Mr. L. B. Stillwell: I should like to point out briefly certain general considerations which engineers should keep in mind when they have occasion to deal with this problem of selecting a system for the electrical equipment of interurban or other railway lines.

While the problem presents itself in each instance as a question of selection of a system to meet certain definite requirements, a correct solution must take into account certain general considerations which at first sight are not obviously included in the local problem.

We have in the United States something like 220,000 miles of railway lines operated by steam. We have in our cities and towns many thousands of miles of track used by electrically-driven equipment and practically all of this equipment is operated by direct current at a potential of from 500 to 600 volts.

Outside our cities, great progress has been made in supplementing transportation facilities by what are generally called interurban railways. In Illinois, Indiana and Ohio, approximately 25 per cent of the aggregate steam railroad mileage is today paralleled by these interurban electric lines. These for the most part are operated by the direct-current system at 600 volts, but a few are using the single-phase alternating-current system and a few others recently have been equipped with 1200-volt direct-current apparatus.

Several of the great steam railroad companies recently have expended large sums of money in equipping certain of their terminals in large cities with electric power and at least one (the Great Northern Railroad) is using electricity to operate its

trains on a short section of a mountain division where special difficulties imposed by tunnel and grade had to be met.

It requires no argument to prove that the time has arrived in the application of electric motive power to transportation when special solutions adapted to specific local problems should be avoided unless they are in line with general tendencies; in other words, engineers investing millions of other peoples' money are bound to direct these expenditures, so far as practicable, along lines which recognize the natural and inevitable tendency in railroad work to standardize everything essential to interchange of traffic.

Mr. Eveleth's paper admirably compares the 1200-volt and the 600-volt direct-current systems in the field of interurban transportation and, within the limits of the problem which he considers, the advantages of the 1200-volt system are manifest. Broadly speaking, his paper presents figures which show that the higher voltage possesses advantages which in certain kinds of service are more than an offset to its disadvantages.

It is an obvious and fair deduction that the possibilities and limitations of voltages still higher must be carefully considered. A comparison of the 1200-volt direct-current system with a 10,000-volt single-phase or three-phase alternating-current system, as applied to the operation of heavy passenger and freight trains such as are operated by the steam railroads of the country, would show advantages for the latter analagous to those which the 1200-volt system possesses when compared with the 600-volt system in the class of service which Mr. Eveleth considers.

There are two methods by which electric railway service outside the zone of natural application of the 600-volt system can be standardized with respect to those things which are essential to interchange of rolling stock. One is the method which Germany has adopted. Essentially it consists in (1) careful study by a competent commission of the broad problem of railway electrification; (2) selection of that system which present knowledge points to as best adapted to a general solution; and (3) concentration of effort in perfecting the details of a system selected.

The other is the method which thus far we are trusting to in America. This method assumes that each specific problem of electrification is to be considered independently of present or future relations. It ignores the obvious fact that the horizon of present "zones of electrification" is sure to expand in the near future and that these horizons in many instances are certain to overlap before the expiration of a proper period of amortization of the capital invested in the apparatus selected. It trusts to the future to find a method of writing off whatever capital may be wasted by reason of short-sighted special solutions, secure apparently in the conviction that the owners of the property will find a method, and also equally secure in the belief that the premature scrap heap is not a source of loss to the

manufacturer of electrical apparatus whatever it may represent to the purchaser.

One question which engineers should keep carefully in mind is this: What part is the 1200-volt system destined to play in the future extension of the application of electric motive power to transportation.

Germany has adopted the single-phase system at 15 cycles and 10,000 volts.

In America, opinion is divided. We are using as substitutes for steam locomotives the single-phase alternating-current system at 25 cycles and 11,000 volts, the three-phase alternating-current system at 25 cycles and 6600 volts, the direct-current system at 600 volts; and in each case electric locomotives more powerful than the heavy steam locomotives which they displaced are in effective and satisfactory service. The consensus of opinion now is in favor of 15 cycles rather than 25 cycles for single-phase working and, as Mr. Eveleth has shown, the 1200-volt direct-current system possesses substantial advantages as compared with the 600 volt direct-current system for work outside city boundaries. The difficulty which electricity faces, therefore, in challenging the superiority of steam in the field of transportation is not poverty of resources but embarrassment of riches.

Two years ago, Mr. H. St. Clair Putnam and the speaker presented a paper before the Institute in which we advocated the early standardization of those things essential to interchange of traffic, *e. g.*, the location of third rail, the frequency used in alternating-current systems, and the height of the overhead trolley. The cross fire under which we found ourselves was unusually animated and vigorous. Since that time, however, some progress has been made. The engineers of both the leading American companies manufacturing electrical apparatus for traction purposes agree that where single-phase apparatus is used the frequency should be 15 cycles per second. Probably it is safe to assume also that the height of the trolley wire above track in the case of single-phase equipment has been practically agreed upon; at any rate, the New Haven engineers have selected a height which appears to meet all requirements and any engineer who may adopt in future a different location will find it necessary to justify his choice by very strong reasons.

In the cities we have the 600-volt direct-current system. Few will dispute that if we were today called upon to electrify any very large proportion of the existing steam railroads of the United States the 15-cycle single-phase alternating-current system would be chosen. Undoubtedly the use of other systems, such as the 1200-volt direct-current system, under conditions and for certain kinds of service intermediate between the trolley service of the city and trunk line service on our great railways, is justified in certain cases, but the engineer who recognizes tendencies and recalls the rapidity with which the use of electricity has

expanded hitherto in the fields which it has entered, will be reluctant to adopt an intermediate system except in cases where his decision rests upon reasons unquestionably controlling.

Mr. Eveleth: You may expect to hear me express an opinion as to whether or not the 1200-volt system would be adequate for the New Haven situation. I do not consider myself in a position to express an opinion at this time. I am not sufficiently familiar with the conditions and have not studied the problem in detail to analyze the various requirements. Without a thorough study of the situation, a guess as to whether 1200-volts would or would not be applicable would be meaningless.

I agree with Mr. Murray's objections to the complications of the combined single-phase and direct-current systems. I heartily agree with Mr. Stillwell in his expression of opinion that we should go slowly about adopting any system that will add complication to a situation already very complicated. Both of these conditions were borne in mind and it was to meet both of these broad and very important considerations that the particular potential of 1200-volts has been selected instead of 1500, 1800 and 2000, any of which would have been applicable for interurban practice. By the use of 1200 volts direct current on the trolley, and motors wound for 600 volts, the car may be operated at the same speed on either 600- or 1200-volt trolleys by connecting the motors all in parallel for 600-volt operation and two in series and two groups in parallel on a 1200-volt section. By exactly doubling the voltage we thus take advantage of the economy of higher voltage with minimum complication of equipment.

One road is now successfully running with motors wound directly for 1200 volts on each commutator. The choice of individual motor voltage is one of the questions which must be considered in any particular case, as they may be wound for either 600 or 1200 volts.

The reason I have gone no further in the comparisons than conditions assumed under *A* is merely that the 1200-volt system is a new arrival and I do not know into what field it may extend. In this connection I am reminded of the answer that Benjamin Franklin gave to some inquirer who had seen the first baloon ascension. The man asked what good it was and Franklin said: "What good is a new born baby?" We cannot tell and we do not know where these things are going to end.

The trend of the future will depend on the operation of what we have, to a very large extent. What has been done in electrification of steam roads is comparatively small. Even in the case of the N. Y. N. H. & H. R. R. it is my understanding that the total cost of electrification is only about 3 per cent of the investment which the New Haven road has made for improvements in its system in the last seven years. Looking at the matter broadly, for the sake of unification we could afford to discard the millions of the present investments in steam road

electrification if a commission along the lines that Mr. Stillwell mentioned were sufficiently competent and foresighted to decide on exactly the right system for future development.

Conditions in this country are vastly different from the conditions abroad. The Government here has practically no control over the equipment of railroads. The principal influence there, which is unknown to us, is the question of military transportation which, for flexibility, necessitates a uniform equipment for an entire country.

The choice of a system for heavy traction is quite a different problem from the choice for interurban service. Just as one tool fits one class of work, and another tool fits another class of work so there seems to be at the present time no one system best for all classes of service. I would regret very much to be considered an advocate of any one system. I hope to see the single-phase system ultimately make good because it has been the most promising from its inception on account of the apparent advantages in distribution, simplicity and cost.

A paper presented at the meeting of the American Society of Mechanical Engineers New York, April 12, 1910, the American Institute of Electrical Engineers co-operating

MOTOR APPLICATION TO MACHINE TOOLS

BY CHARLES FAIR

The subject of motor application to machine tools is rather a difficult one to treat satisfactorily in an abstract way. However, in this paper I shall try to point out the fundamental principles underlying motor applications to machine tools and trust that these will aid, not only in the selection of the proper motor and control, but in their application to machine tools as well. Observing these principles will have a marked effect upon production and will reduce maintenance to a minimum.

Since much has been written on the advantages of motor-driven tools, it will suffice here to mention briefly only a few; such as sanitation, unobstructed light, absence of belts and belt troubles, head room for cranes, hoists, etc., elasticity of arrangement, ease of adding new tools and of moving and rearranging tools, close speed regulation, greater power and overload capacity, maximum output of tools, power transmission, facility for running only such tools as are required for overtime work, and finally, under modern structural conditions, avoidance of the well-understood difficulties of line shaft installations in cement buildings. These points are admirably illustrated in the following photographs.

Figs. 1 and 1a are views showing the interior of a machine shop of a large manufacturing company. As this is one of the largest buildings ever built to be used exclusively as a machine shop, it would probably not be amiss to give here a brief description of the building and the machines.

The building is 295 ft. wide and 800 ft. long. The total floor space of the building, including galleries is 490,000 sq. ft. or 11.2 acres. It contains 997 machine tools operated by 1047

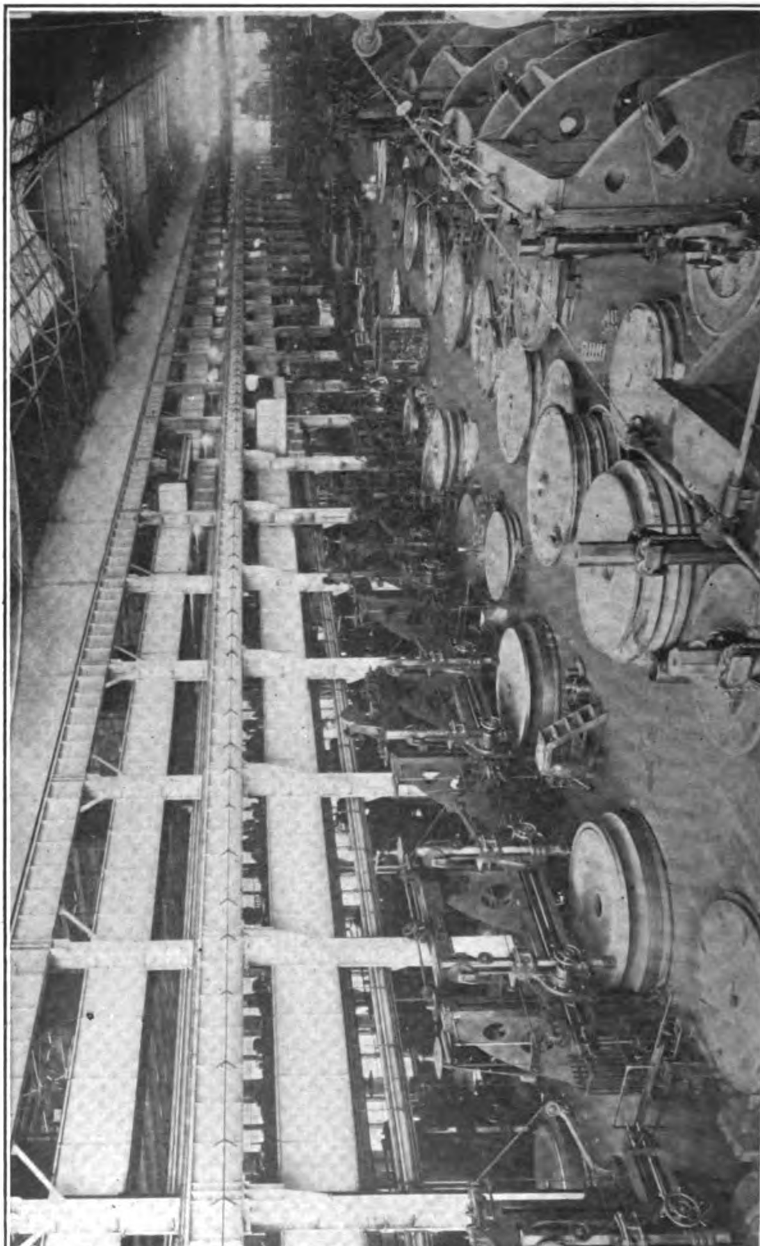


FIG. 1

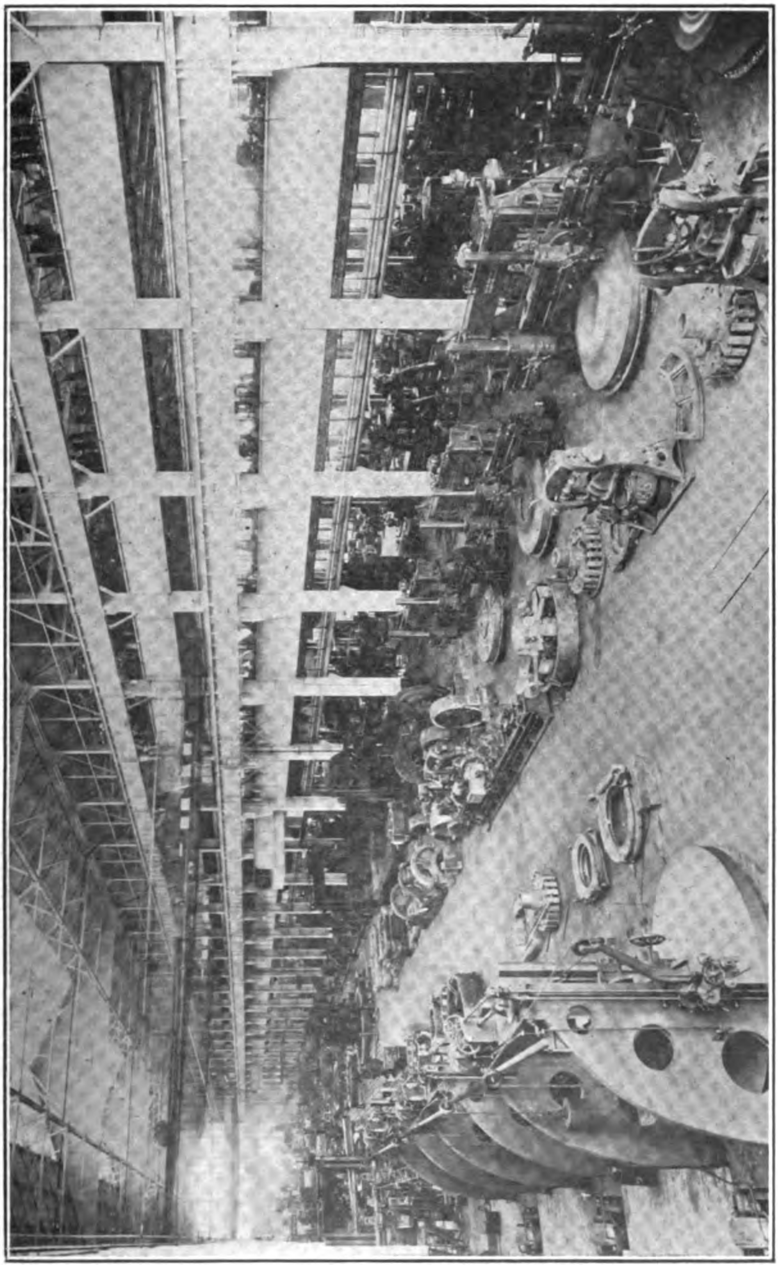


Fig. 1a

motors, 941 of the tools being driven by independent motors, and a number of them requiring two or more motors. There are 56 of the smaller tools, all of which are located in the second gallery, which are arranged in groups varying from six to twelve tools per group. The machines range in size from a 40-ft. boring mill down, there being 51 boring mills 6 ft. and over, and 36 portable tools used on the iron floors. This large number of tools requires for handling work, 35 cranes ranging from 5 to 50 tons and 8 electric hoists, as well as 8 freight elevators and 2 gantry cranes.

Fig. 2 is a very good illustration of the overhead clearance due to the use of individual motors and shows a number of 8-ft. boring mills. Each of these mills is driven by a 20-h.p. adjustable-speed motor, the cross-rail being raised and lowered by a 3-h.p. motor. The controllers for operating both motors are shown fastened to a bracket which in turn is bolted to the machine. These machines are placed under a gallery, as shown in the illustration, as also are the boring mills shown in Fig. 3. The latter are placed directly behind those shown in the previous illustration, thus making a very compact arrangement of tools and at the same time allowing plenty of room for handling work. Except in the case of the first mill on the left, the controllers for operating this group of boring mills are arranged as shown on the first mill on the right.

Fig. 4 is a view of another building looking down the center aisle of the second floor. This shop is a modern reenforced concrete building in which no line shafting whatever is used, even though the majority of the tools are old ones changed over to individual motor drive. Although many of these tools require short belts, this is a very different matter from belting from lineshaft to countershaft and from countershaft to tool.

Fig. 5 shows a group of lathes driven by individual motors. If this group of lathes were belt-driven and arranged as compactly as shown, with two belts from line to countershaft, the ceiling would be literally a mass of belts.

Fig. 6 shows a punch press department. All the punches and shears in this building are individually driven by alternating-current motors, although such tools are also frequently driven by direct-current motors.

Up to comparatively few years ago in the majority of the shops where motors were used, they were simply belted to the lineshaft or countershaft of the tool. Adjustable-speed motors were not

so commonly used then as now, nor were they made in the great variety of sizes and speeds now obtainable. Today, especially in the case of new tools with their requirements of higher power

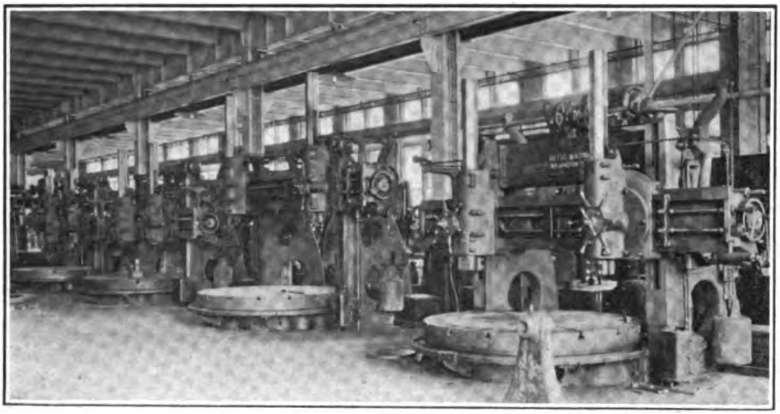


Fig. 2

and closer speed regulation, due to the use of high-speed steel, it becomes not only more convenient, but in many cases almost a necessity, to apply the motor directly to the tool.

Fig. 3

When the work of actually equipping a factory with motor drives is undertaken, it will be necessary to study the conditions of operation, which vary greatly with the product manufactured.

FIG. 4

FIG. 5

and while in some cases these conditions are comparatively simple in others they are more complex. The arrangement of tools will to a large extent depend upon the nature of the work, and as to whether alternating or direct current is available; it will also depend upon whether the convenience of operation and handling of material are of sufficient importance to call for a considerable number of individual drives, or as to whether it is to be generally a group-driven shop.

In driving tools with individual motors it will be remembered that the motor not only supplies the power and speeds best adapted to the tool, but that the speed of the motor alone in many cases covers the entire speed range of the tool, and that the motor can be applied directly to the tool, making a compact unit.

Fig. 6

When equipping tools with individual drives, the controlling apparatus as well as the motor should be attached directly to the tool when possible. This arrangement allows moving the tool by simply disconnecting the leads and connecting them in the new position. In the case of portable tools this, of course, is an absolute necessity.

A graphic recording wattmeter in circuit with a tool not only tells the actual power consumed by the machine, but also shows whether the tool is operating at its maximum rate, by registering the time of unproductive cycles or the length of time the tool is idle; and by analysis, the cause of the lost time may be discovered and result in a change of conditions with a corresponding

increase in production. Poor lineshaft alignments have been detected by watching the integrating wattmeter. Many shops are paying dearly for lack of attention to alignment of shafts, etc.

Difficulties concerning the choice of the type of motors for tools have been considerably exaggerated. The following table will, in a general way, aid in the choice of motors. The great variety and the sizes of tools of the same name make it necessary in a general list, such as this to double-check a number of tools.

MOTORS FOR MACHINE TOOLS

Tool	Direct current			Alternating current		
	Shunt	Comp.	Series	×	#	✻
Bolt cutter	†			×		
Bolt and rivet header		20% 40%		×	#	
Bulldozers		20% 40%		×	#	
Boring machines	†			×		
Boring mills	†			×		
Raising and lowering cross rails on boring mills and planers		60%	†		#	
Boring bars	†			×		
Bending machines		20% 40%		×	#	
Bending rolls		40% 80%	†			✻
Corrugating rolls		20% 40%		×	#	
Centering machines	†			×		
Chucking machines	†			×		
Boring, milling and drilling machines	†			×		
Drill, radial	†			×		
Drill press	†			×		
Grinder—tool, etc	†			×		
Grinder—castings		20%		×		
Gear cutters	†	20%		×		
Hammers—drop		20% 30%			#	
Keyseater—milling—broach	†			×		
Keyseater—reciprocating	†	20%		×		
Lathes	†			×		✻+
Lathe carriages			†		#	
Milling machines	†			×		

MOTORS FOR MACHINE TOOLS—(Continued)

Tool	Direct current			Alternating current		
	Shunt	Comp.	Series	×	#	✱
Heavy slab milling	†	20%		×		
Pipe cutters	†			×		
Punch presses		20% 40%		×	#	
Planers		20%		×	#	
Planers—rotary	†	20%		×		
Saw—small circular	†			×		
Saw—cold bar and I beam	†	20%		×		
Saw—hot		20%		×		
Screw machine	†			×		
Shapers	†	20%		×		
Shears		20% 40%		×	#	
Slotters	†	20%		×		
Swaging		20%		×	#	
Tappers	†			×		
Tumbling barrels or mills		20%		×		

× Squirrel cage rotor.
Squirrel cage rotor-high starting torque.
✱ Slip ring induction motor with external rotor resistance.
† Might be used for tire lathes as it allows slowing down when cutting hard spots.

It must be kept in mind, however, that various circumstances, such as size or roughness of work, flywheel capacity, etc., may call for radical departures in choice of motors, this list being compiled to meet average conditions. Shunt motors, for instance, are used in the following cases; when the work is of a fairly steady nature; when considerable range of adjustment of speed is required, as on lathes and boring mills; and on group and lineshaft drives, etc.

Compound-wound motors are used where there are sudden calls for excessive power of short duration, as on planers, punch presses, etc.

Series motors should be used where speed regulation is not essential and where excessive starting torque and slow starting speeds are required; as, for instance, in moving carriages of large lathes, in raising and lowering the cross rails of planers and boring mills, and for operating cranes.

When in doubt as to the choice of compound or series motors of small horse power, the choice might be determined by the sim-

plicity of control in favor of the series motor. Series motors, however, should never be used when the motor can run without load, as the speed would accelerate beyond the point of safety.

The alternating current motor of the squirrel cage rotor type corresponds to the constant-speed, shunt, direct-current motor, but with a high-resistance rotor it approaches more closely the characteristics of a compound direct-current motor. It is understood that the variable-speed machines, checked in this list under the alternating-current squirrel cage rotor column, have the necessary mechanical speed changes.

The slip-ring induction motor with external rotor resistance would be used for variable speed, but this must not be construed to mean that it corresponds to a direct-current, adjustable-speed motor, as it has the characteristics of a direct-current shunt motor with armature control.

The self-contained, rotor resistance type would be used for lineshaft drives, and for groups when of sufficient size.

Multi-speed, alternating-current motors are those giving a number of definite speeds, usually 600 and 1200 or 600, 900, 1200 and 1800 rev. per min., and are made for both constant horse power and constant torque. These motors would be used where alternating current only was available, or direct current limited; and the speed range of the motor, together with one or two change gears, would give the required speeds.

One of the most important features in the selection of motors and one that is persistently overlooked, is the strict adherence to the use of standard motors, and by standard motors is meant standard armature shafts as well. The importance of maintaining standard armature shafts will be readily recognized by the factory management when it is pointed out that by such an arrangement spare armatures are reduced to a minimum, and that in an emergency it is possible, where these are not carried, to replace an armature or even a whole motor, from an idle tool, or from a tool of relatively less importance at the time. Also, of course, stock motors can be supplied promptly by the manufacturer and shipments materially improved if special shaft extensions are not called for. That special features in a motor are sometimes desirable, is not to be denied; it may so happen that the advantages from some special feature in the motor may more than offset the disadvantages above referred to, but in cases where these features are thought necessary they should be carefully considered before final decision.

The sketches in Fig. 7 show a number of arrangements used in order to maintain standard motor shafts. In addition to these, many forms of flange and split couplings are used. The method which is selected for connecting standard shafts will depend upon the conditions surrounding the drive under consideration. Tools which only a few years ago were equipped with special motors are today driven by standard motors, and as a result are easily and quickly repaired. In the early days of the motor

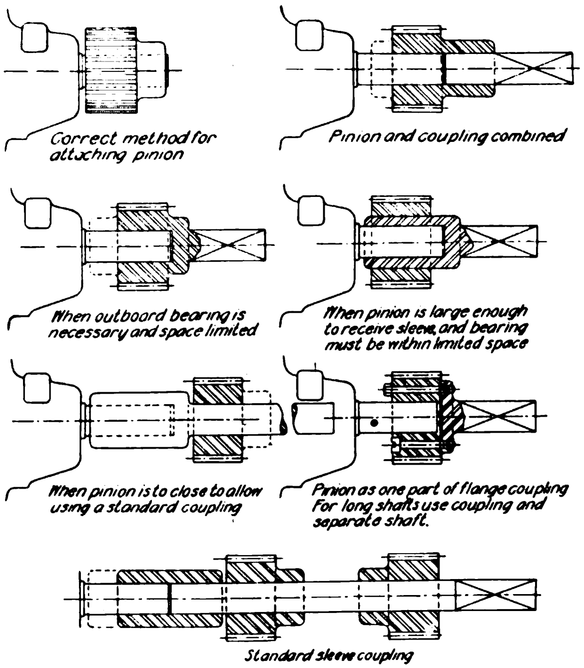


FIG. 7.—Some methods used to maintain standard motor shafts for the interchanging of armatures

drive many special features were thought necessary in the motor to make it adaptable to the tool; special frames, shafts and speeds were required by the tool builder, and little thought was given to the interchangeability of parts. It is therefore easy to recognize in these early equipments responsibility for the existing idea that special features in the motor are still necessary for tool equipments. Many of these features are now recognized as unnecessary, and today the tool builder in many instances builds his tools ready for attaching standard motors.

At the present time, so far as tools are concerned, we think of the motor largely as a means of driving the tool and not of the possibilities of the motor becoming the main element of the tool construction. Here again, high-speed steels, together with the improvements made in the motor, will produce many new designs in tools with corresponding higher efficiencies.

The old prejudice existing against the electric motor, which was mostly a mistrust due to a lack of familiarity with its operation, is rapidly dying out, and today motors are found driving machines in shops of every description.

Equally important with the choice of motors is that of control. In selecting the control it is necessary to consider the nature of the work, its accessibility to the operator, the method of attaching it to the tool and in some cases its relative position to other tools; for instance, an open type starting rheostat should not be exposed to danger of short-circuit from flying chips. In the majority of cases, a shunt motor of ¾ h.p. and less would be started by a switch. Exceptions to this would be motors on tools that must be gotten under way slowly, and grinders driven by direct-current motors for reasons of safety. With adjustable-speed motors, care should be taken to throw the switch on full field. Series motors up to 8 h.p. or even larger can be started by switch. Exceptions to this would be cranes and tools requiring a certain amount of armature speed regulation. Larger motors, for tools where starting service is infrequent or not severe, and for lineshafts and for group drives, would be satisfactorily operated with a dial type controller, which is cheaper than the drum controller, provided, however, that the controller is placed in a protected position.

When making the installation, accessibility to the controller in case of accident should be kept in mind, even though of little importance so far as starting up is concerned. The starting apparatus should be placed where the motor or some of the moving parts can be seen by the operator. On individual motor-driven tools, where the motor is started and stopped many times a day or where the starting conditions are of a severe nature, or where tools are edged along, drum type controllers with extra heavy starting resistance should be used. For adjustable-speed motors, using the drum type control, the field control should be through fingers making contact on segments of the controller drum and not by sliding contacts on a dial, as with the latter, trouble will develop sooner or later. Motors above 40 or 50 h.p.,

under these severe conditions, are best operated by a master controller which operates contactors for cutting out steps of starting resistance, and if adjustable-speed, the field control should be taken care of, as stated above, by fingers making contact on segments of the drum. This class of starting apparatus will stand any quantity of abuse and, by the addition of a simple current limit relay device, becomes practically a fool-proof protection for the motor. There are cases where it might be advantageous to use master controllers and contactors even with smaller motors.

Alternating-current squirrel cage rotor type motors, two-phase and three-phase, up to 5 or 8 h.p., generally speaking, can be

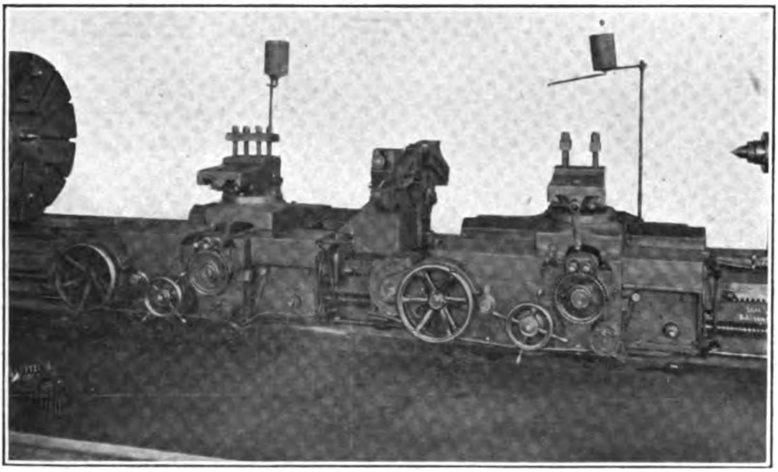


FIG. 8

thrown on the line, depending largely upon power conditions. Above 5 or 8 h.p. they should be operated by compensators. The self-contained rotor-resistance type would be started by a sliding resistance in the rotor, and the slip-ring type by a controller with external resistance.

Upon the convenient arrangement of the control depends, to a considerable degree, the output of the tool, and the importance of the arrangement from the standpoint of the operator cannot be ignored, since the output of a tool will be materially increased when an operator can start and stop the tool and obtain at all times maximum cutting speeds by simply turning a handle. The controller must be placed in a safe position and should be ac-

cessible for repairs, which very often means that some arrangement is necessary to bring the operating handle within easy access of the operator. A familiar illustration of the convenience of control is the arrangement so commonly seen on lathes, whereby the operating handle travels with the tool carriage and allows the operator at all times a complete control of his tool. The motor and control for moving lathe carriages is perhaps not quite so familiar; such an arrangement is shown in Fig. 8, which shows a 60-ft. lathe, the main drive being a 35-h.p. 635/1270-rev. per min. motor and the carriages being operated by a 3½-h.p.

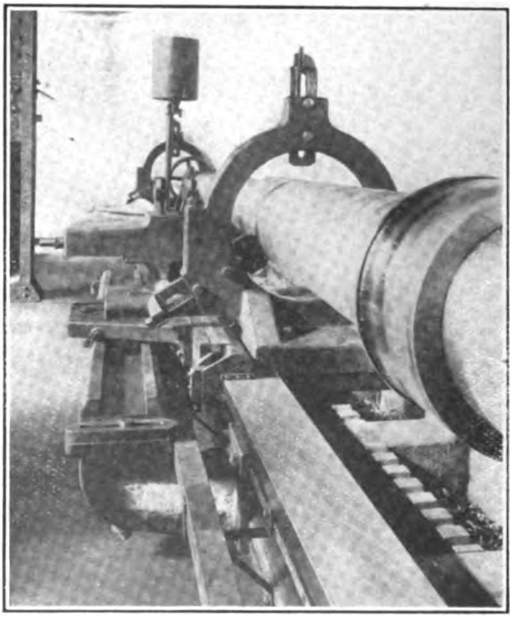


Fig. 9

series motors, while Fig. 9 shows the method of fastening and protecting the trolley for operating the motors on the lathe carriages. The latter illustration shows a 42 in. lathe, and was selected because in addition to the regular method of fastening the trolley it shows the change necessary in the supporting brackets if taper attachment be used. Strange as it may seem, this most important feature, the convenience of control, which bears directly on production, is ignored in the majority of the tools where the control is of the greatest importance. This convenient arrangement of control is shown in the following illustrations.

Fig. 10 shows an 8-ft. boring mill, driven by a 20-h.p., 600/1200-rev. per min. adjustable-speed motor. The cross-rail is raised and lowered by a 3-h.p. motor. It was a very easy matter in this case to place the controllers in the most accessible position for the operator by fastening them to a bracket which in turn is bolted to the machine. Boring mills on which it is not convenient to have the controller placed as shown in Fig. 10, might be arranged as in Fig. 3, previously shown, which calls for an extension of the controller shaft, a coupling, a bearing

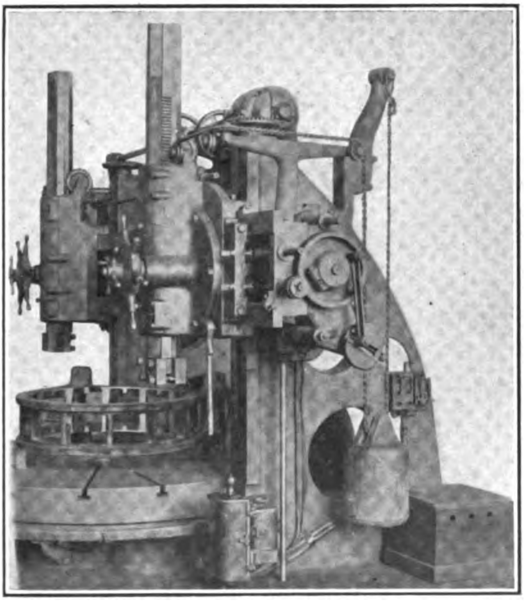


FIG. 10

bracket and an operating wheel; or again as in Fig. 11, which shows the arrangement of control on a 16–25-ft. boring mill, which is operated much as the one shown above but with the addition of a universal joint. This mill is driven by a 50-h.p., 500/1000-rev. per min. adjustable-speed motor, and two 15-h.p. constant-speed auxiliary motors.

In the case of the vertical milling machine shown in Fig. 12, it was desirable to provide two positions for the control—one that at all times could be operated from the floor line, and one traveling with the cutters, which at times might be ten feet or

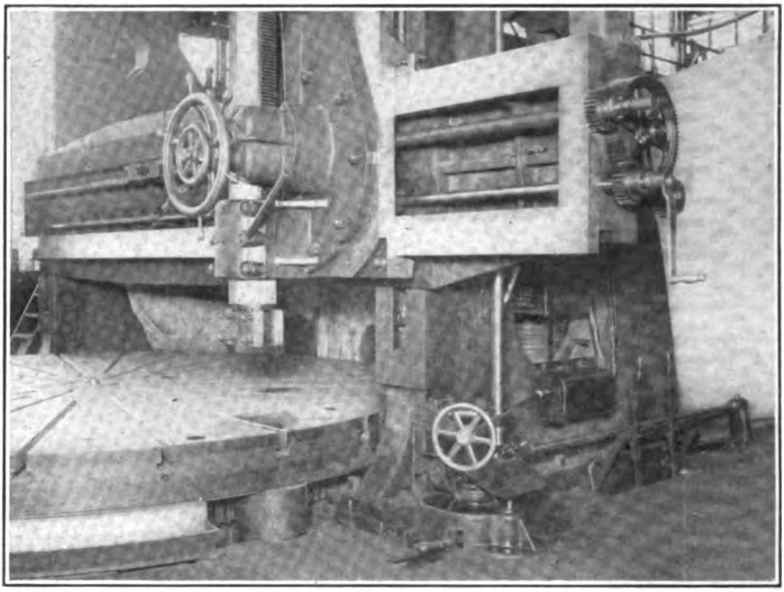


FIG. 11

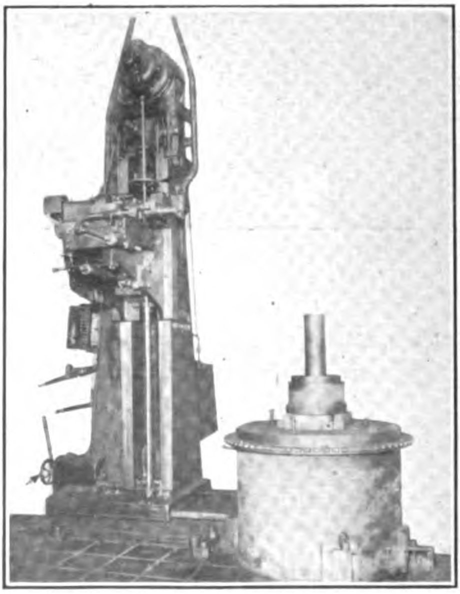


FIG. 12

more from the floor. On account of the limited space for the controller it was necessary, in order to bring the operating wheel in the proper position for the operator, to use spur gears, universal joint, and bevel gears.

Fig. 13 shows a vertical milling machine, driven by a 7½ h.p., constant-speed motor, and shows clearly the operating wheel together with the safety latch which drops in place when the controller is brought to the off position.

On slotters it is often necessary to put the controller on the

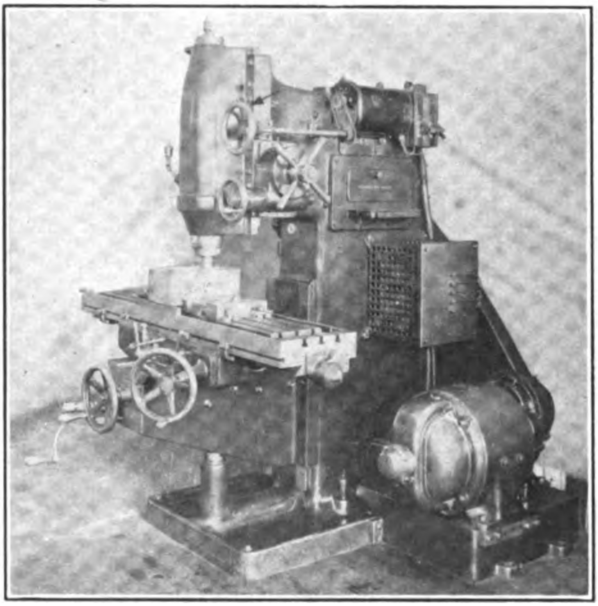


FIG. 13

left side of the tool with the operating handle on the right, as shown in the case of a 12-in. slotter, Fig. 14, driven by a 5-h.p., 500/1500-rev. per min., adjustable-speed motor.

Fig. 15 is a 60-in. slotter, driven by a 20-h.p., 890/1330-rev. per min., adjustable-speed motor through pneumatic clutches, and for moving the table a 3-h.p. motor is used. Two controlling stations were necessary on this machine, the work at times being so large that it was not practicable to operate the front wheel, yet for the majority of the work it was the most satisfactory position. The safety latch for the off position is clearly shown on

the operating wheel. The controller is seen on the rear of the machine.

In the case of the milling machine driven by a 5-h.p., 500/1500-rev. per min., adjustable-speed motor, shown in Fig. 16, it was at times, on account of the nature of the work, essential that the operating handle be placed in the position shown.

Fig. 17 shows the motor and controller travelling with the head of an 84-in. rotary planer, driven by a 15-h.p., constant-speed motor, the current being received through sliding contact which is on the rear of the machine and is completely enclosed.

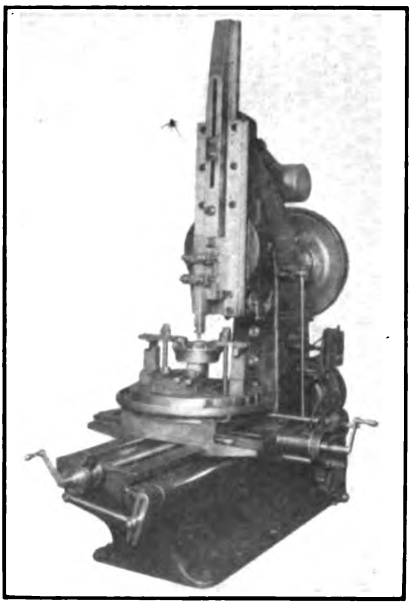


FIG. 14

The controller is placed under the platform, while the controller handle is brought out at the top of the pedestal as shown.

The horse power required for driving tools calls for the exercise of considerable judgment, especially in the case of alternating current motors where power factor enters into consideration. Exhaustive tests have been made to determine the amount of power required to drive tools, but it is to be regretted that many of these tests are lacking in essential features that would make them valuable. Conclusions drawn from incomplete data are apt to be misleading; as in the case of tests made with motors

which are considerably underloaded or overloaded, and where efficiencies are not taken into consideration; or where the material used and duration of test are not stated; or where there has been failure to state whether the test was a practical one or merely a breakdown test. The conclusions drawn from breakdown tests are often deceptive and should not be used for determining power to drive tools; also it does not follow that a tool which stands up longer than another under breakdown conditions, will do the same under practical conditions. The majority of the formulas now in existence for computing horse power required for tools

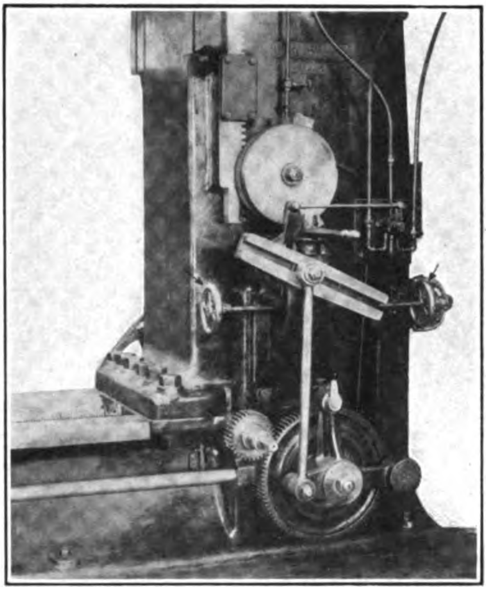


Fig. 15

are generally misleading and useless, and no general formula that would be of practical value has been developed, as the power required varies with the metal worked, the cutting speed and many other conditions.

The construction of the tool is seldom taken into consideration when estimating horse power, yet some of the worm-driven tools are notoriously inefficient. Other tools are so constructed that the greatest part of the power delivered to the tool is consumed in friction losses and not in useful work; again, the tool may be constructed upon approved lines but may not be stiff enough to

stand the strains to which it is subjected, thereby causing considerable loss of power, all of which, as well as the difference in power due simply to the shape of a cutting tool, has been repeatedly proved by tests. In one instance, it required 72 per cent more power to drive a plain spiral milling cutter than the same cutter nicked.

The advent of the high-speed steel and the high-power tools, together with the increased speed of old tools, makes much of the data bearing on horse power collected up to a comparatively short time ago, of somewhat doubtful value. From the above,

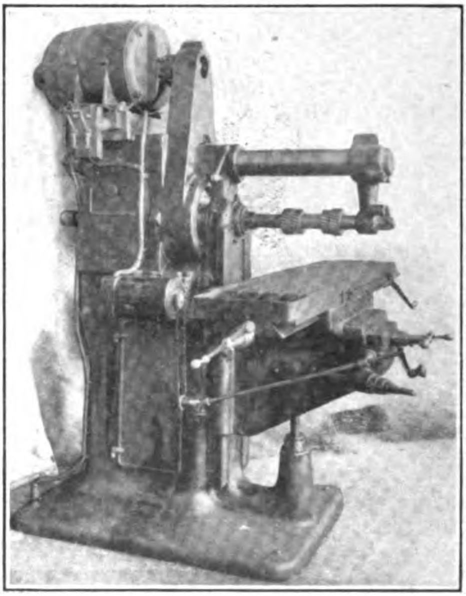


Fig. 16

and from the fact that the duty required of a tool in one shop may be more severe than that in another, it will be seen that it cannot be accurately stated that a definite size of motor is required for a given tool. In the majority of cases, however, the horse power for small tools has been pretty well fixed. With the larger tools the variation in horse power required is much more pronounced, and at the same time, is more important on account of the size of the motors involved. This variation in horse power is often as much as 4 to 1 and sometimes even 6 to 1.

Considerable difference of opinion has developed as to the

advantages of individual versus group drives, and while it is generally agreed that it is advantageous to have the larger tools individually driven, the agreement by no means extends to the smaller ones. Under certain conditions there is no question as to the advantages of the individual drive for small tools, as, for instance, where small tools are necessarily placed among larger ones, or to allow convenient placing of tools in the assembling departments. The cases where it would be advantageous to have small individually-driven tools are numerous.

Little trouble is experienced in obtaining new tools already

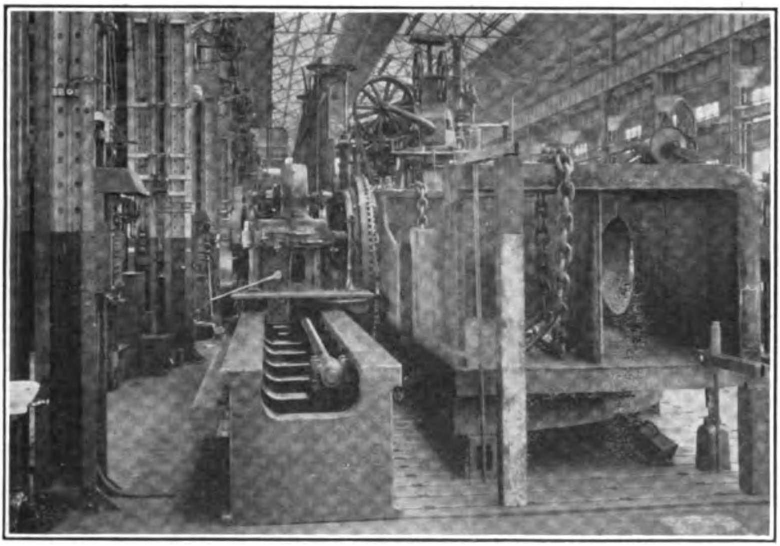


FIG. 17

arranged for attaching motors, since many of the tool manufacturers are alive to the superiority of the motor drive and have for years built tools especially adapted for motor drives. Unfortunately, others have seen fit merely to arrange them for attaching motors, while still others leave the purchaser to attach the motor as best he can, consequently the best results are not always obtained.

When the driving of old tools by individual motors is under consideration, it is important to take into account the nature of the work, the speed range, the number of similar tools to be equipped and the condition of the tool. It sometimes happens

that when a tool in itself would not call for an individual drive, certain circumstances might make such a drive advisable.

As an illustration, when the majority of tools in a shop have become individually driven, there might still remain a number of scattered tools, which, unless they were driven by individual motors, would necessitate the running of a long line of shafting; or, in the event of moving into new quarters—a cement building perhaps—it is decided not to use line shafting. It is understood, of course, that when old tools are scrapped the motors can be transferred to other tools.

Some interesting methods for attaching motors to old tools are shown in the following illustrations.

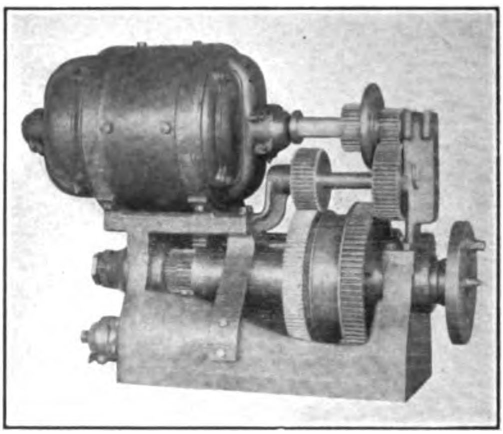


Fig. 18

Fig. 18 shows the headstock of what was originally a belted type, 24-in. lathe changed to a motor drive. This equipment makes a very durable and satisfactory drive, and calls for a standard 5-h.p., 500/1500-rev. per min., adjustable-speed motor. The shaft carrying the sliding pinions and handwheel is made large enough to receive the motor shaft, thus avoiding the use of a special armature shaft. The illustration shows clearly the motor, motor base, yoke, gears, bearing bracket and the quill which replaced the old cone. Room was left between the sliding pinion and gears in order that the pinions might be turned freely when sliding from one gear to the other.

The 30-in. lathe, shown in Fig. 19, is driven by a 5-h.p. motor, and like the lathe shown in Fig. 18, is a most satisfactory drive.

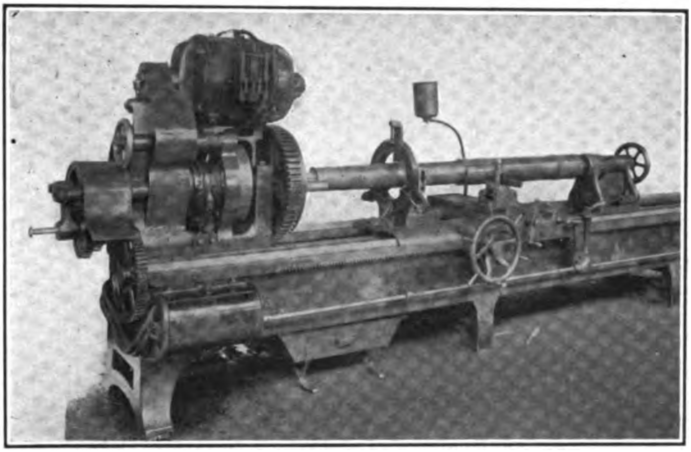


FIG. 19

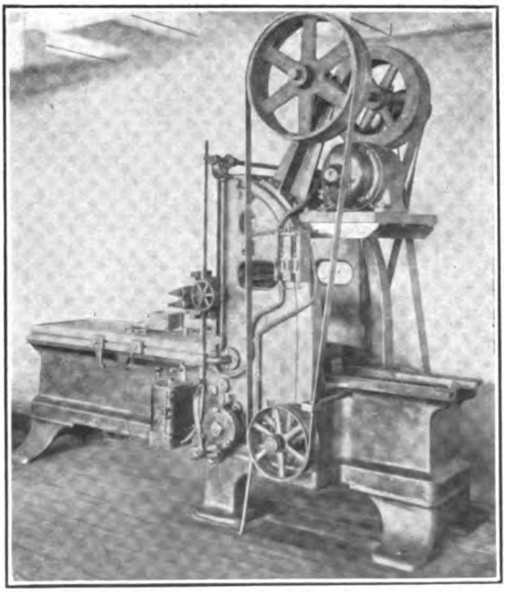


FIG. 20

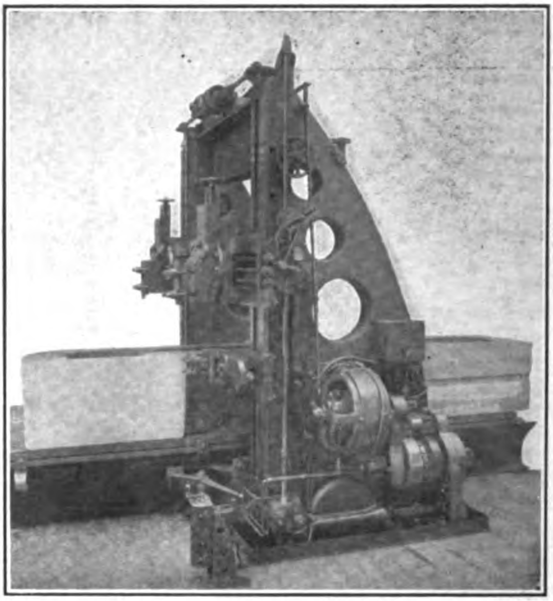


Fig. 21

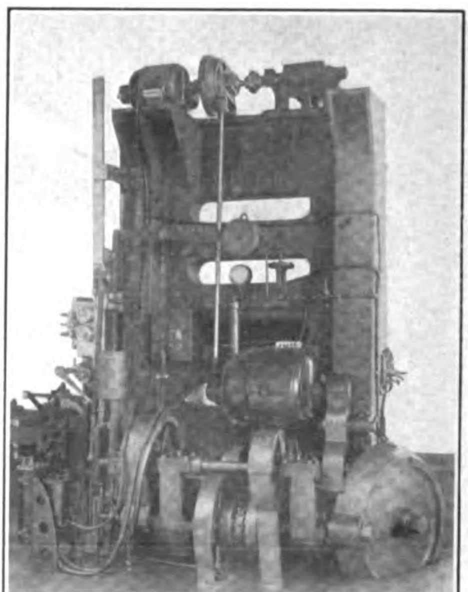


Fig. 22

It differs from the former principally in the use of a positive clutch instead of sliding pinions. These lathes, as well as the majority of lathes which are motor-driven, are operated by a handle fastened to the right side of the lathe carriage to give the operator at all times complete control over his tool.

Fig. 20 shows a 24-in. planer. This is an inexpensive way of driving planers up to 42-in. or thereabouts, and has proved highly satisfactory. It is a decided advantage to have the controller conveniently located even on planers.

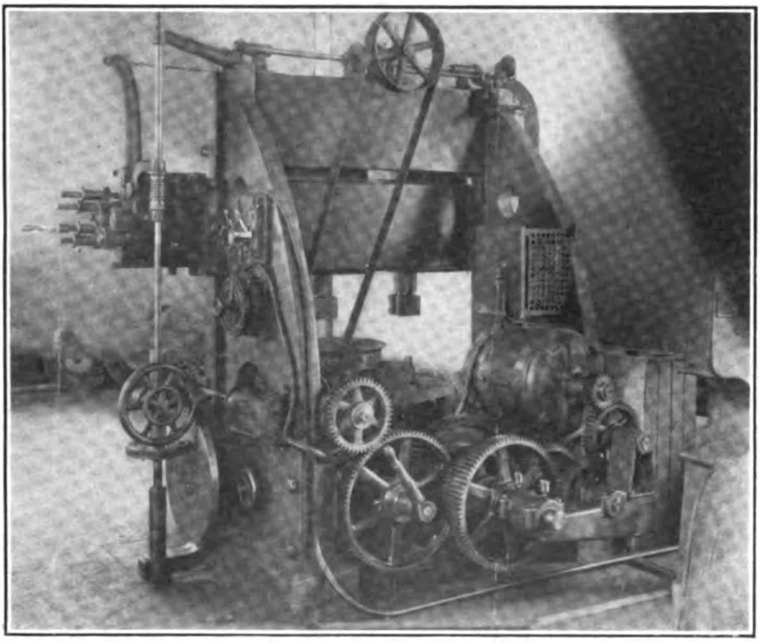


Fig. 23

Fig. 21 shows an old 120-in. planer driven through pneumatic clutches. In this case there was not room for the controllers on the machine so they were placed in the most convenient position for the operator, as shown. The small controller at the rear of the large one is for operating the motor which raises and lowers the cross-rail of the planer.

Fig. 22 shows clearly the small motor for raising and lowering the cross-rail on a 72-in. planer. The main drive, which is through pneumatic clutches, is also clearly shown.

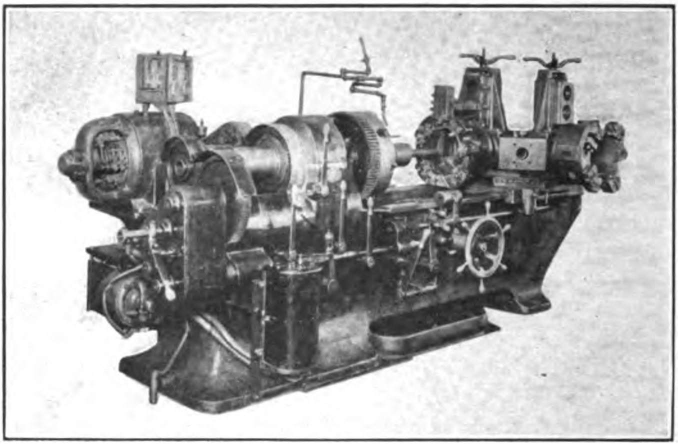


Fig. 24

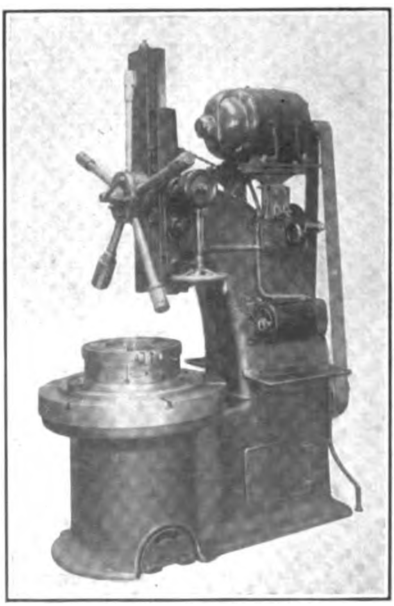


Fig. 25

Fig. 23 shows a 60-in. boring mill changed to motor drive, the cone having been replaced by gears and motor as shown.

Fig. 24 shows a turret lathe driven by a 7½-h.p., 500/1500-rev. per min., adjustable-speed motor, and a ¾-h.p., constant-speed motor.

Fig. 25 is a 36-in. chucking machine driven by a 5-h.p., 500/1500-rev. per min., adjustable-speed motor, and shows a very simple method of attaching the motor; in fact, the brackets for supporting the motor were originally made for an entirely different machine.

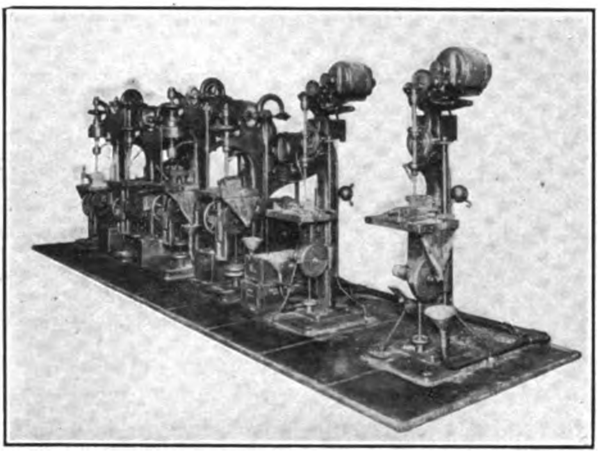


Fig. 26

Fig. 26 is a group of drills driven by adjustable-speed motors. It would be hard for one who had seen the original group to recognize this group of drills as the one originally driven by ropes, counterweights, etc.

The application of motors to tools, whether old or new, is not a difficult matter, and from the foregoing illustrations and the explanatory comments we trust that the advantages claimed for such applications have been made fairly evident.

NOTE

The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **San Francisco, May 5-7, 1910**. This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper, if too late to be used at the meeting, should be mailed to **Ralph D. Mershon, 60 Wall St., New York,** and if received prior to June 1 will be treated as if presented at the meeting.

A paper to be presented at the 248th meeting of the American Institute of Electrical Engineers, San Francisco, Cal., May 5-7, 1910

(*Subject to final revision for the Transactions.*)

PARALLEL OPERATION OF THREE-PHASE GENERATORS WITH THEIR NEUTRALS INTERCONNECTED.

BY GEORGE I. RHODES

Neutral Currents

The difficulty of operating three-phase star-connected generators with their neutrals in parallel, was most forcibly brought to the attention of the engineering world when the company with which I am connected attempted to operate its plants in this manner. The various phenomena of this attempt have been fully described by C. W. Ricker (Experience with a Grounded Neutral on a High-tension Plant, *Electric Journal*, September, 1906) and by the writer (Experience with a Grounded Neutral on the High Tension System of the Interborough Rapid Transit Company, Transactions A.I.E.E., Vol. XXVI, Part II, page 1605).

The subject of neutral currents has been discussed considerably. It is generally understood that they are of triple frequency and are produced by those harmonics of e.m.f. which cannot exist between the lines of a three-phase system. A general review of the theory of these conditions may not be out of place.

Let there be given a three-phase star-connected generator which develops in its three coils A, B and C electromotive forces represented by the equations

$$e_A = E_k\,(k_1 \sin \alpha + k_3 \sin 3\alpha + \ldots\ k_9 \sin 9\alpha + \ldots)$$

$$+ E_l\,(l_1 \cos \alpha + l_3 \cos 3\alpha + \ldots\ l_9 \cos 9\alpha + \ldots)$$

$$e_B = E_k\,[k_1 \sin (\alpha - 120°) + k_3 \sin 3(\alpha - 120_\circ)$$
$$+ \ldots\ k_9 \sin 9(\alpha - 120°)\ \ldots)$$

$$+E_l\,(l_1 \cos(\alpha-120°) + l_3 \cos 3(\alpha-120°) + \ldots\; l_9 \cos\; 9(\alpha-120°) \ldots]$$

$$e_C = E_k\,[k_1 \sin(\alpha+120°) + k_3 \sin 3(\alpha+120°) + \ldots\; k_9 \sin 9(\alpha+120°) \ldots)$$

$$+E_l\,(l_1 \cos(\alpha+120°) + l_3 \cos 3(\alpha+120°) + \ldots\; k_9 \cos\; 9(\alpha+120°) \ldots]$$

$$\text{Now } 3\,(\alpha \pm 120°) = 3\alpha \pm\; 360° = 3\alpha$$

$$9\,(\alpha \pm 120°) = 9\alpha \pm 1080° = 9\alpha$$

These equations may now be written

$$e_A = E_k\,[k_1 \sin \alpha + k_3 \sin 3\alpha + \ldots\; k_9 \sin 9\alpha + \ldots)$$

$$+E_l\,(l_1 \cos \alpha + l_3 \cos 3\alpha + \ldots\; l_9 \cos 9\alpha + \ldots]$$

$$e_B = E_k\,[k_1 \sin(\alpha-120°) + k_3 \sin 3\alpha + \ldots\; k_9 \sin 9\alpha + \ldots)$$

$$+E_l\,(l_1 \cos(\alpha-120°) + l_3 \cos 3\alpha + \ldots\; l_9 \cos 9\alpha + \ldots]$$

$$e_C = E_k\,[k_1 \sin(\alpha+120°) + k_3 \sin 3\alpha + \ldots\; k_9 \sin 9\alpha + \ldots)$$

$$\pm E_l\,(l_1 \cos(\alpha+120°) + l_3 \cos 3\alpha + \ldots\; l_9 \cos 9\alpha + \ldots]$$

The e.m.f. between phases A and B is $e_{AB} = e_A - e_B$.

It is evident from an inspection of the above equations that there is no third harmonic or multiple thereof in this wave. The same condition is true also of the potentials between the other phases.

If this generator be connected to a balanced Y-connected impedance a current will flow of such wave form and magnitude that the e.m.f. between A and O, B and O, and C and O differs from the generated potential only by containing no triple harmonics (Fig. 1). This phenomena is due to the fact that since these harmonics are not present between the lines no currents of corresponding frequency can flow. It is evident that there will exist between N and O a potential represented by the triple harmonics in the coil waves.

If the points N and O be connected a current will flow limited by the parallel impedance of the three circuits. The currents in the three lines will be in phase with each other and hence of one third the magnitude of that flowing in the neutral connection.

If instead of a load, another generator be connected to the first, a difference of potential will exist between their neutrals equal to the vector difference of the third harmonics in their coil wave forms. If the machines are exactly similar, are running at exactly the same load with the same excitation, and have at all times exactly equal instantaneous angular velocities this

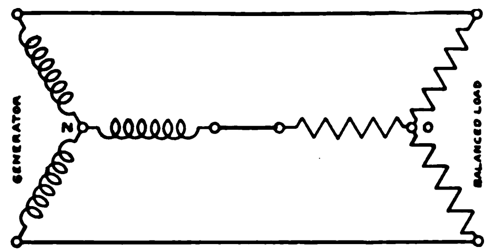


FIG. 1

potential will be zero, and no current can flow if the neutrals be connected. An inequality in any one of the above conditions will cause a neutral potential or current as the case may be.

It is the purpose of the following discussion to show a means by which the magnitude of these potentials and currents may

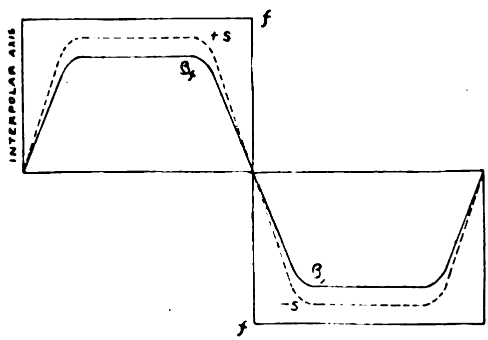


FIG. 2

be approximately calculated from the no-load characteristics of a machine.

Alternators as usually built have their field windings concentrated in a single coil per pole and the desired e.m.f. wave form is secured by varying the shape of the pole face.

This variation in the pole shape has the effect of varying the susceptibility per unit area and hence the flux distribution.

if f = excitation m.m.f. at any point.
s = susceptibility at any point.
α = angular distance of point from interpolar axes.
$f = \pm F$.

$$s = \pm S_k \{k_1 \sin \alpha + k_3 \sin 3\alpha + k_5 \sin 5\alpha + \ldots\}$$
$$\pm S_l \{l_1 \cos \alpha + l_3 \cos 3\alpha + l_5 \cos 5\alpha + \ldots\}$$

$$= \pm S_k \sum_{a=1}^{a=n} k_a \sin a\,\alpha \pm S_l \sum_{a=1}^{a=n} l_a \cos a\,\alpha$$

where the + sign holds from $\alpha = 0$ to $\alpha = \pi$ and
the − sign from $\alpha = \pi$ to $\alpha = 2\pi$.

The − sign in the equation for susceptibility is due to the fact that its value must everywhere be positive.

If β_f = no load flux density at any point.

$$\beta_f = f\,s = F\,S_k \sum_{a=1}^{a=n} k_a \sin a\,\alpha + F\,S_l \sum_{a=1}^{a=n} l_a \cos a\,\alpha \qquad \text{(I)}$$

In any conductor moving through this flux, there will be generated an e.m.f. of the same wave form. In a distributed winding the e.m.f. generated will be the vector sum of the e.m.f's. of the individual conductors. As a result, the higher harmonics in the potential wave will be relatively smaller in magnitude than those in the flux wave. This phenomena has been very fully discussed by Comfort A. Adams in his paper on the Voltage Ratio in Synchronous Converters with Special Reference to the Split-Pole Converter, TRANSACTIONS, A.I.E.E., Vol. XXVII, Part II, page 959.

In alternators as usually constructed, the armature winding is distributed over 60 electrical degrees of space under each pole. The reduction factors under these conditions may be obtained from the above mentioned paper on page 966 and are as follows:

For triple harmonics $\frac{2}{n}$

(II)

For all other harmonics $\frac{1}{n}$

For example, if there is a third harmonic of 10 per cent in the flux wave, there will be a similar harmonic of two-thirds of 10 per cent in the e.m.f. wave.

It appears from the above discussion that having given the no-load e.m.f. wave, the flux distribution may be obtained.

In a loaded polyphase armature there is developed a m.m.f. which may be expressed by the equation

$$\text{A} = A_v \;\{v_1 \sin \alpha + v_3 \sin 3\,\alpha + v_5 \sin 5\alpha + \;.\;.\;.\;\}$$

$$+ A_w \;\{w_1 \cos \alpha + w_3 \cos 3\alpha + w_5 \cos 5\alpha + \;.\;.\;.\;\}$$

$$= A_v \sum_{b=1}^{b=n} v_b \sin b\,\alpha + A_w \sum_{b=1}^{b=n} w_b \cos b\,\alpha$$

This m.m.f. will produce a flux β_a

$$\beta_a = a\,s = \left(A_v \sum_{b=1}^{b=n} v_b \sin b\,\alpha + A_w \sum_{b=1}^{b=n} w_b \cos b\,\alpha\right)$$

$$\times \left(\pm S_k \sum_{a=1}^{a=n} k_a \sin a\,\alpha \pm S_l \sum_{a=1}^{a=n} l_a \cos a\,\alpha\right)$$

$$= \pm S_k A_v \sum_{a=1}^{a=n} \sum_{b=1}^{b=n} k_a\, v_b \sin a\,\alpha \sin b\,\alpha$$

$$\pm S_l\, A_w \sum_{a=1}^{a=n} \sum_{b=1}^{b=n} l_a\, w_b \cos a\,\alpha \cos b\,\alpha$$

$$\pm S_k\, A_w \sum_{a=1}^{a=n} \sum_{b=1}^{b=n} k_a\, w_b \sin a\,\alpha \cos b\,\alpha$$

$$\pm S_l\, A_v \sum_{a=1}^{a=n} \sum_{b=1}^{b=n} l_a\, v_b \cos a\,\alpha \sin b\,\alpha$$

Only odd values of the quantities a and b are to be considered.

This equation may be transformed into a Fourier's series as follows:

$$\beta_a = \sum_{a=1}^{a=n} \sum_{b=1}^{b=n} \sum_{N=1}^{N=n} \left[\left\{ S_k\, A_v\, k_a\, v_b \right.\right.$$

$$\times \frac{1}{\pi} \left[\frac{2\,N}{N^2-(a-b)^2} - \frac{2\,N}{N^2-(a+b)^2}\right]$$

$$\left.\left. + S_l\, A_w\, l_a\, w_b \times \frac{1}{\pi} \left[\frac{2\,N}{N^2-(a-b)^2} + \frac{2\,N}{N^2-(a+b)^2}\right]\right\} \sin N\,\alpha\right.$$

$$+\left[\left\{S_k A_w k_a w b \frac{1}{\pi}\left[\frac{2(a-b)}{(a-b)^2-N^2}+\frac{2(a+b)}{(a+b)^2-N^2}\right]\right.\right.$$

$$\left.\left.+S_l A_v l_a v_b \times \frac{1}{\pi}\left[-\frac{2(a-b)}{(a-b)^2-N^2}+\frac{2(a+b)}{(a+b)^2-N^2}\right]\right\}\cos N\alpha\right] \tag{III}$$

A more specific idea of this equation may be gained if all harmonics other than the fundamental in the susceptibility and the armature reaction m.m.f. be neglected. It will be well to neglect, also, the cosine terms in the no-load flux distribution. Under these conditions we have,

No-load flux

$$\beta_f = F\,S\,k_1 \sin \alpha$$

Armature reaction flux

$$\beta_a = \frac{2}{\pi}\sum_{N=1}^{N=n} S\,A_v\,k_1\,v_1\left[\frac{1}{N}-\frac{N}{N^2-4}\right]\sin N\alpha$$

$$+S\,A_w\,k_1\,w_1\left[\frac{2}{4-N^2}\right]\cos N\alpha$$

$$= SA_v k_1 v_1 \{0.848 \sin \alpha - 0.170 \sin 3\alpha + \quad . \; . \; -0.004 \sin 9\alpha + \ldots\}$$

$$+ SA_w k_1 w_1 \{0.424 \cos \alpha - 0.254 \cos 3\alpha + \quad . \; . \; -0.017 \cos 9\alpha + \; . \; . \}$$

The conditions called for in this equation are those which approximately obtain in an alternator of usual construction having a pure sine no-load wave form, and an armature with a distributed winding. It is evident that even with this favorable wave form the reaction will produce a very considerable triple harmonic flux.

In the above equation, the cosine terms correspond to that component of the current in phase with the internal e.m.f. and the same terms to that component at 90 deg. therewith. The relative magnitudes of these reaction fluxes for equal components are shown graphically in Fig. 3. The solid lines represent the sine terms, and the dotted, the cosine. Only the third harmonic has been included. If all the higher harmonics were included the flux due to that component of the current in phase with the internal e.m.f. would be zero at the interpolar axis.

In most alternators, however, the no-load coil e.m.f. contains a third harmonic. In order to make further discussion reasonably complete and yet not too complicated this harmonic will be included. It will be assumed also that the wave is symmetrical with respect to the polar axis.

Under these conditions we have,

Excitation flux:

$$\beta_f = F\,S\,\{k_1 \sin\alpha + k_3 \sin 3\,\alpha\}$$

Armature reaction m.m.f.

$$\text{A} = A_v\, v_1 \sin\alpha + A_w\, w_1 \cos\alpha, \text{ where } v_1 = w_1$$

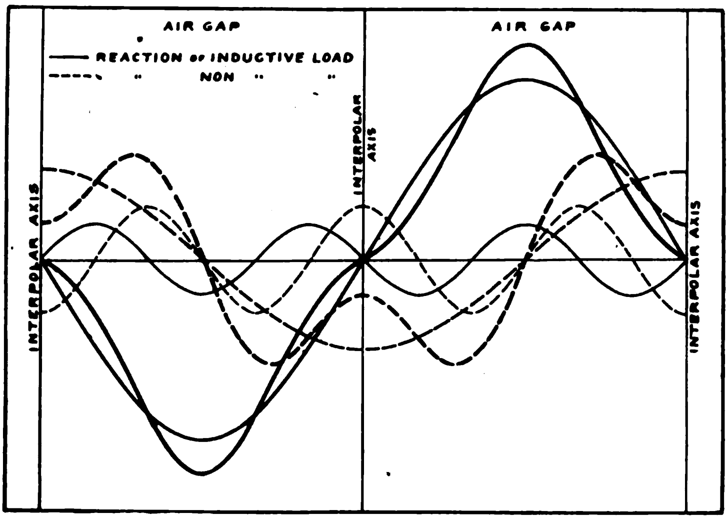


FIG. 3

Armature reaction flux

$$\begin{aligned}\beta_a = S\,A_v\, v_1\, \{&(0.848\,k_1 - 0.17\,k_3)\sin\alpha \\ &- (0.170\,k_1 - 0.65\,k_3)\sin 3\,\alpha \\ &\cdots\cdots\cdots\cdots \\ &- (0.004\,k_1 + 0.01\,k_3)\sin 9\,\alpha \\ + S\,A_w\, w_1\, \{&(0.424\,k_1 - 0.25\,k_3)\cos\alpha \\ &- (0.254\,k_1 - 0.62\,k_3)\cos 3\,\alpha \\ &\cdots\cdots\cdots\cdots \\ &- (0.017\,k_1 + 0.02\,k_3)\cos 9\,\alpha\end{aligned}$$

These equations are made more useful by a further transformation.

$$\text{Let } F\,S = F'$$

$$\text{and } S^2\left[(A_v\,v_1)^2 + (A_w\,w_1)^2\right] = (A')^2$$

ϕ = angle between the current and the excitation e.m.f., negative if lagging.

Then

$$A_v\,v_1 = A' \sin \phi$$

$$A_w\,w_1 = -A' \cos \phi$$

$$\therefore \beta_f = F' \{k_1 \sin \alpha + k_3 \sin 3\,\alpha\} \qquad \text{(IV)}$$

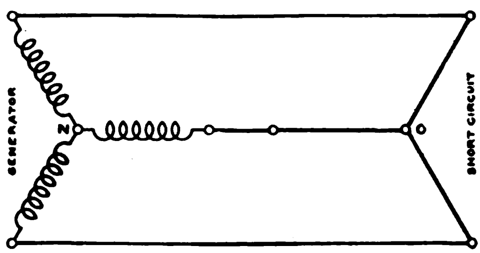


FIG. 4

$$\begin{aligned}
\beta_a = A' \sin \phi\ \{&(0.848\,k_1 - 0.17\,k_3) \sin \alpha \\
&- (0.170\,k_1 - 0.65\,k_3) \sin 3\,\alpha \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&- (0.004\,k_1 + 0.01\,k_3) \sin 9\,\alpha\} \\
- A' \cos \phi\ \{&(0.424\,k_1 - 0.25\,k_3) \cos \alpha \\
&- (0.254\,k_1 - 0.62\,k_3) \cos 3\,\alpha \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&- (0.017\,k_1 + 0.02\,k_3) \cos 9\,\alpha\} \qquad \text{(V)}
\end{aligned}$$

As an illustration of the use of these equations let us consider the case of an alternator running under short circuit for the usual test. (Fig. 4).

Let X = leakage reactance per phase.
X_r = reaction reactance per phase.
$X_s = X + X_r$ = usual synchronous reactance.
r = resistance per phase.

Neglecting r, ϕ becomes -90 deg.

$$\therefore \beta_a = -A' \{(0.848\, k_1 - 0.17\, k_3) \sin \alpha$$
$$- (0.170\, k_1 - 0.65\, k_3) \sin 3\, \alpha$$
$$\ldots\ldots\ldots\ldots\ldots\ldots$$
$$- (0.004\, k_1 + 0.01\, k_3) \sin 9\, \alpha\}$$

The resultant fundamental flux is of a magnitude necessary to produce an e.m.f. equal to the leakage reactance drop.

Therefore, considering fundamentals only,

$$\beta_a = -\beta_f \left[1 - \frac{x}{x_s}\right] = -\frac{X_r}{X_s}\, \beta_f$$

or

$$-(0.848\, k_1 - 0.17\, k_3)\, A' = -\frac{X_r}{X_s}\, F'\, k_1$$

$$\therefore A' = +\frac{X_r}{X_s} \left(\frac{k_1}{0.848 k_1 - 0.17\, k_3}\right) F'$$

hence

$$\beta_a = -\frac{X_r}{X_s}\ \frac{F'\, k_1}{(0.848 k_1 - 0.17 k_3)} \{(0.848\, k_1 - 0.17\, k_3) \sin \alpha$$
$$- (0.170\, k_1 - 0.65\, k_3) \sin 3\, \alpha$$
$$- (0.004\, k_1 + 0.01\, k_3) \sin 9\, \alpha\}$$

The resultant flux $\beta = \beta_f + \beta_a$.

$$\beta = \frac{X}{X_s}\, F'\, k_1 \sin \alpha$$

$$+ F' \left\{ \left[k_3 + \frac{X_r\, (0.170\, k_1 - 0.65\, k_3)\, k_1}{X_s\, (0.848\, k_1 - 0.17\, k_3)} \right] \sin 3\, \alpha \right.$$

$$\left. + \left[\frac{X_r\, (0.004\, k_1 + 0.01\, k_3)\, k_1}{X_s\, (0.848\, k_1 - 0.17\, k_3)} \right] \sin 9\, \alpha + \ .\ .\ . \right\}$$

This triple harmonic flux produces an e.m.f. of similar wave form which will appear between N and O. Its value may be obtained as follows

The e.m.f. generated by the excitation flux on open circuit is

$$e_f = \sqrt{2}\, E_f \left\{ k_1 \sin \alpha + \frac{2}{3}\, k_3 \sin 3\, \alpha \right\} \tag{VI}$$

The neutral potential, then, is

$$e_0 = \sqrt{2}\, E_f \left\{ \frac{2}{3} \left[k_3 + \frac{X_r\, (0.170\, k_1 - 0.65\, k_3)\, k_1}{X_s\, (0.848\, k_1 - 0.17\, k_3)} \right] \sin 3\, \alpha \right.$$

$$\left. + \frac{2}{9} \left[\frac{X_r\, (0.004\, k_1 + 0.01\, k_3)\, k_1}{X_s\, (0.848\, k_1 - 0.17\, k_3)} \right] \sin 9\, \alpha + \ . \ . \ . \right\} \tag{VII}$$

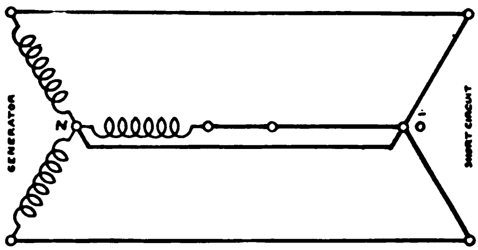


Fig. 5

If the points N and O, Fig. 5, are connected, a current will flow equal to

$$I_3 = \frac{\text{root-mean-square } e_0}{X_{r3} + X_3}$$

where X_{r3} = reaction reactance for the third harmonic current.
X_3 = leakage reactance for third harmonic current.

It is evident that the leakage flux is practically independent of the frequency of the current hence

$$X_3 = 3\, X$$

The value of X_{r3} may be obtained as follows:

Referring to Fig. 6 it is seen that the distribution of the third harmonic flux is such that we practically have a generator of three times the actual number of poles. Since the m.m.f.

of armature reaction is proportional to the number of turns per pole the m.m.f. for the triple frequency reaction is approximately one-third of that for an equal fundamental armature current.

The different relative angular spaces occupied by the coils when referred to the triple frequency and to the fundamental flux distribution will have a considerable effect on the armature reactions. The windings are distributed over 60 fundamental degrees or 180 third-harmonic degrees. The effect of this distribution is approximately the same on armature reaction as on e.m.f. That is, the m.m.f. of a triple harmonic current is two-thirds of that due to an equal fundamental.

Combining the effects of the increase in effective number of poles and of distribution of winding gives a triple harmonic

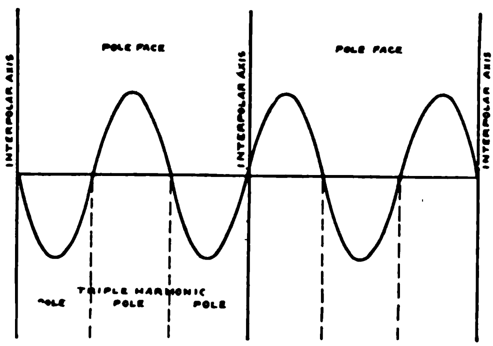


FIG. 6

m.m.f. two-ninths of the m.m.f. that would be produced by a fundamental current of the same magnitude.

It may be expressed by the series

$$A_3 = A_{v3} \sum_{a=1}^{a=n} v_{a3} \sin 3\, a\, \alpha + A_{w3} \sum_{a=1}^{a=n} w_{a3} \cos 3\, a\, \alpha$$

This equation neglects entirely the fluctuations of the reaction which is virtually single-phase.

The equation for the flux distribution may be obtained by substituting the proper values in equation III which is applicable to the product of any two Fourier's series.

Neglecting all higher harmonics than the fundamental (*i.e.*, third) in the m.m.f. and the third in the no load flux distribution,

together with the cosine terms in this latter, we get for the triple harmonic flux,

$$\begin{aligned}\beta_{a3} = S\, A_{v3}\, v_{3\cdot 3}\ \{ & (-0.1697\, k_1 + 0.65\, k_3) \sin \alpha \\ & + (0.655\, k_1 + 0.28\, k_3) \sin 3\,\alpha \\ & \cdots\cdots\cdots\cdots\cdots \\ & + (-0.014\, k_1 - 0.06\, k_3) \sin 9\,\alpha + \ldots\ldots \} \\ + S\, A_{w3}\, w_{3\cdot 3}\ \{ & (-0.255\, k_1 + 0.11\, k_3) \cos \alpha \\ & + (0.618\, k_1 + 0.14\, k_3) \cos 3\,\alpha \\ & \cdots\cdots\cdots\cdots\cdots \\ & + (-0.022\, k_1 - 0.08\, k_3) \cos 9\,\alpha + \ldots\ldots \}\end{aligned}$$

Reducing this equation to a form corresponding to that for armature reaction with fundamental current, (V) we get

$$\begin{aligned}\beta_{a3} = A'_3 \sin \phi_3\ \{ & (-0.170\, k_1 + 0.65\, k_3) \sin \alpha \\ & + (0.655\, k_1 + 0.28\, k_3) \sin 3\,\alpha \\ & + \cdots\cdots\cdots\cdots\cdots \} \\ - A'_3 \cos \phi_3\ \{ & (-0.255\, k_1 + 0.11\, k_3) \cos \alpha \\ & + (0.618\, k_1 + 0.14\, k_3) \cos 3\,\alpha \\ & + \cdots\cdots\cdots\cdots\cdots \} \qquad \text{(VIII)}\end{aligned}$$

In which ϕ_3 is the angle the triple harmonic current makes with the e.m.f. generated by the resultant flux.

From the discussion above

$$A'_3 = \frac{2}{9}\, A'$$

The relative values of armature reaction for the third harmonic and the fundamental currents are in the same proportion as the reaction fluxes. Thus

$$\frac{X_{r3}}{X_r} = \frac{2}{9}\ \frac{(0.655\, k_1 + 0.28\, k_3)}{(0.848\, k_1 - 0.17\, k_3)}$$

$$X_{r3} = \frac{2}{9} \times \frac{(0.655\, k_1 + 0.28\, k_3)}{(0.848\, k_1 - 0.17\, k_3)}\, X_r \qquad \text{(IX)}$$

for currents lagging 90 deg., as is the case on short circuit.

For currents in phase with the third harmonic e.m.f. the reaction is approximately the same as may be seen by a comparison of the coefficients of the third harmonic sine and cosine terms in equation VIII. The reaction of the fundamental current in phase with the e.m.f. is, similarly, approximately half its value for currents 90 deg. with the e.m.f. (equation V.)

It should be noticed that the third harmonic current produces a fundamental flux which aids the excitation. This effect however is small, for with a neutral current of three times the short-circuit current, that is, with a triple frequency armature current equal to the fundamental, the flux generated is only $2/9 \times (0.170\, k_1 - 0.65\, k_3)\, F'$; only a few per cent, even with this abnormal neutral current.

It is evident from the foregoing discussion that with a machine short circuited as in Fig. 5, a neutral current will flow which is approximately equal to the neutral potential as calculated by equation VII divided by the sum of the leakage reactance and reaction reactance as determined by equation IX. This is probably the simpler method of calculating the current, although it may be obtained by properly equating the fluxes.

In making calculations as to the behavior of a machine under load it is necessary to express the load current as a fraction of the short circuit current, with the same excitation. The work is considerably simplified if an estimate is made of the angle between the load and the excitation e.m.f. A short preliminary computation will serve to determine this angle. When the power factor is unity it may be taken as one half that usually found by the generally used e.m.f. method of determining the regulation of an alternator.

Proceeding along these lines

Let E_f = root-mean-square value of open circuit voltage.

I = load current.

I_s = short circuit current.

E_{f_3} = no load neutral potential.

$$e_f = \sqrt{2}\, E_f \left\{ \sin p\,t + \frac{E_{f_3}}{E_f} \sin 3\,p\,t \right\} \text{ (See equation (IV)} \qquad \text{(X)}$$

$$e_a = \frac{I}{I_s} \times \frac{X_r}{X_s} \frac{\sqrt{2}\, E_f}{\left[0.848 - \frac{3}{2}\left(0.17 \frac{E_{f_3}}{E_f}\right)\right]} \sin \phi$$

$$\left\{\left[\left(0.848 - \frac{3}{2}\left(0.17 \frac{E_{f_3}}{e_f}\right)\right]\right. \sin p\,t\right.$$

$$- \frac{2}{3}\left[0.170 - \frac{3}{2}\left(0.65 \frac{E_{f_3}}{E_f}\right)\right] \quad \sin 3\,p\,t$$

$$\left. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \right\}$$

$$- \frac{I}{I_s} \times \frac{X_r}{X_s} \frac{\sqrt{2}\,E_f}{\left[0.848 - \frac{3}{2}\left(0.17 \frac{E_{f_3}}{E_f}\right)\right]} \cos\phi$$

$$\left\{\left[0.424 - \frac{3}{2}\left(0.25 \frac{E_{f_3}}{E_f}\right)\right] \cos p\,t\right.$$

$$- \left[0.254 - \frac{3}{2}\left(0.62 \frac{E_{f_3}}{E_f}\right)\right] \quad \cos 3\,p\,t$$

$$\left. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \right\} \qquad \text{(XI)}$$

The sum of these voltages gives the actual e.m.f. generated in the armature. The terminal potential will be this value reduced by the impedance drop, which is, if a sine wave of load current be assumed

$$e_z = \frac{I}{I_s} \times \frac{X}{X_s} \times \sqrt{2}\,E_f \left\{\sin\phi \sin p\,t - \cos\phi \cos p\,t\right\}$$

$$+ \frac{I}{I_s} \times \frac{r}{X_s} \times \sqrt{2}\,E_f \left\{ - \sin\phi \cos p\,t - \cos\phi \sin p\,t\right\} \qquad \text{(XII)}$$

The vector representation of the fundamentals of these equations is as follows (See Fig. 7)

$$P\,D = E_f \left\{ 1 + \frac{I}{I_s X_s} \left[X_r \sin\phi - r \cos\phi + X \sin\phi \right]\right\}$$

$$- j\,E_f \left\{ \frac{I}{I_s\,X_s} \left[\frac{X_r \cos\phi \left[0.424 - \frac{3}{2}\left(0.25 \frac{E_{f_3}}{E_f}\right)\right]}{\left[0.848 - \frac{3}{2}\left(0.17 \frac{E_{3f}}{E_f}\right)\right]} - r \sin\phi - X \cos\phi \right]\right\} \qquad \text{(XIII)}$$

This equation can most conveniently be solved for any case by assuming values for ϕ and making a series of approximations.

Before applying the equations developed above to any particular alternator it will be well to indicate how the necessary no-load characteristics may be found. With respect to the usual open and short circuit curves, nothing need be said.

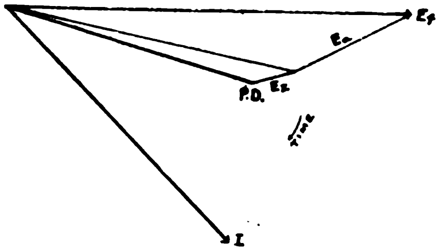


FIG. 7

The magnitude of the third harmonic in the excitation voltage may most conveniently be obtained as follows:

If three transformers (potential transformers) are connected with their primaries in Y and their secondaries connected in $\triangle$, (Fig. 8) it will be impossible for any triple harmonic exciting current to flow in the high tension leads. The necessary third

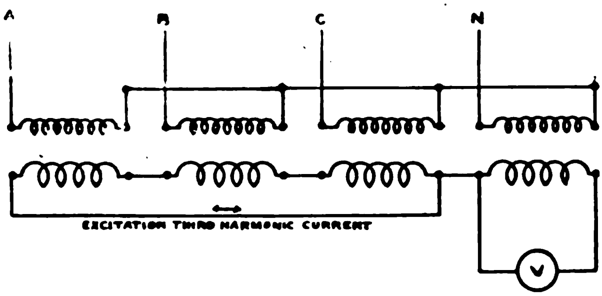


FIG. 8

harmonic current will flow in the secondary windings. Under these circumstances, the potential between the lines and transformer neutral will be equal and can contain no triple harmonics, since they are absent in the line potential. This transformer neutral will thus be the true neutral of the system.

If a transformer and voltmeter be connected between the generator and the transformer neutrals it will indicate the magnitude

of the triple harmonic e.m.f. This same scheme of potential connections may be used to determine the neutral potential under all conditions of load both as to magnitude, and, if an oscillograph be available, as to phase and wave form.

The application of the preceding equations to a specific generator will serve to make them clearer. Fig. 9 shows the no load characteristics of an alternator which will not operate

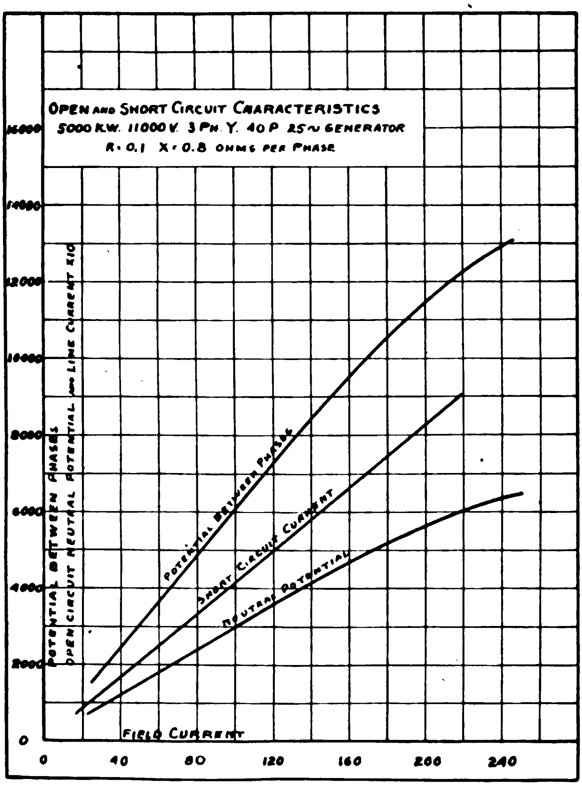


FIG. 9

satisfactorily with others of the same type if the neutrals are interconnected. Fig. 10 shows an oscillograph record on open circuit. The resistance is 0.1 ohm per phase and the leakage reactance is about 0.8 ohm figured on the basis of 10 leakage lines per ampere per inch of embedded conductor.

We have then at 150 amperes field current and the armature short circuited, as in Fig. 4,

$$X_s = \frac{9000}{\sqrt{3}\times 620} = 8.4 \text{ ohms.}$$

$$X = \qquad = 0.8 \text{ ohms.}$$

$$X_r = 8.4-0.8 = 7.6 \text{ ohms.}$$

$$r = \qquad 0.1 \text{ ohms.}$$

The third harmonic e.m.f. $= \dfrac{440\sqrt{3}}{9000} = 0.085$

$$\therefore\ k_3 = \frac{3}{2}\times 0.085 = 0.127$$

Substituting in equation VII

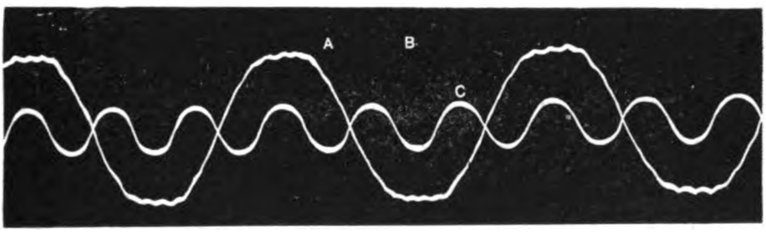


FIG. 10.—A = line to neutral; B = line to line; C = neutral to zero

$$e_0 = \frac{9000\sqrt{2}}{\sqrt{3}}\left\{\frac{2}{3}\left[0.127+\frac{7.6}{8.4}\frac{(.0170-[0.65\times 0.127])}{(0.848-[0.17\times 0.127])}\right\}\right. \sin 3\alpha$$

9th harmonic is negligible.

$$e_0 = 769\sqrt{2}\sin 3\alpha$$

$\therefore$ E_3 = 769 root-mean-square volts.

From equation IX.

$$X_{r3} = \frac{2}{9}\times\frac{(0.655+[0.28\times 0.127])}{(0.848-[0.17\times 0.127])}\times 7.6 = 1.4 \text{ ohms.}$$

$$X_3 = 3\times 0.8 = 2.4 \text{ ohms.}$$

$$X_{s3} = 1.4+2.4 = 3.8 \text{ ohms.}$$

If the neutrals are short circuited as in Fig. 5, a current will flow of $\frac{769}{3.8} = 202$ amperes per phase or $3 \times 202 = 606$ amperes in the neutral. A comparison with results of a test on this alternator as given in Fig. 11 shows an encouraging agreement when it is considered that higher harmonics in the flux distribution other than the third have been neglected.

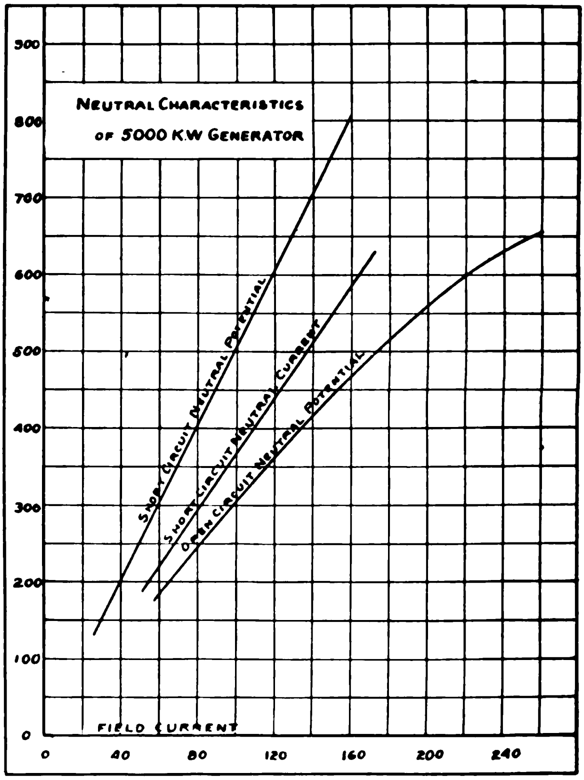


FIG. 11

Fig. 12 is an oscillograph record showing the line current under short circuit with the neutral open, and the neutral potential. Fig. 13 shows line and neutral currents when the neutral connection is made. It is to be noted that the current waves contain negligible higher harmonics.

If this machine had been built with a perfect no-load sine e.m.f. wave there would still be a neutral potential.

$$e_0 = \frac{9000\sqrt{2}}{\sqrt{3}}\left\{\frac{2}{3}\left[0+\frac{7.6\,(0.170-0)}{8.4(0.848-0)}\right]\right\} \sin 3\,\alpha.$$

$E_0 = 628$ root-mean-square volts.

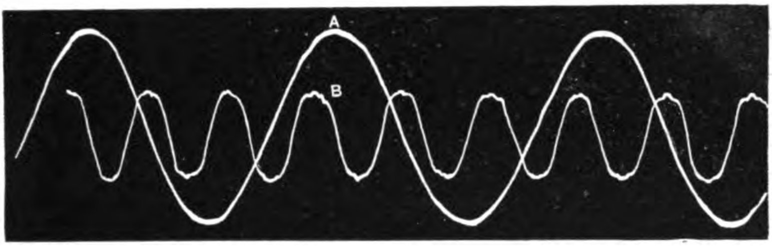


FIG. 12.—Generator short-circuited with neutral open. A = line current; B = neutral potential; Field current = 150 amperes

$$X_{r3} = \frac{2}{9}\times\frac{0.655}{0.848}\times 7.6 = 1.3 \text{ ohms.}$$

$X_3 = 2.4$ ohms.

$X_{s3} = 3.7$ ohms.

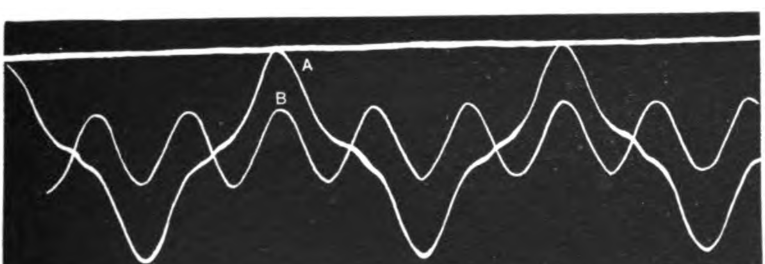


FIG. 13.—Generator short-circuited with neutral closed. A = line current; B = neutral current; field current = 150 amperes

$$I = \frac{3\times 628}{3.7} = 537 \text{ amperes.}$$

A determination both of the magnitude and the phase relationships of the neutral potential when the machine is carrying

load may easily be made by substituting the proper values in equations X, XI and XII.

Let us consider the following case.

Load = 250 amperes, non-inductive.
Excitation = 205 amperes.

$$E_f = \frac{11650}{\sqrt{3}} = 6725 \text{ volts.}$$

$$I_s = 845 \text{ amperes.}$$

$$e_f = 6725\sqrt{2}\,(\sin p\,t + 0.085 \sin 3\,p\,t)$$

$$e_a = \frac{250}{845} \times \frac{7.6}{8.4} \times \frac{6725\sqrt{2}}{[0.848 - \frac{3}{2}(0.17 \times 0.085)]}\Bigg[-$$

$$\Big\{[0.848 - \frac{3}{2}(0.17 \times 0.085)] \sin p\,t$$

$$- \frac{2}{3}[0.170 - \frac{3}{2}(0.65 \times 0.085)] \sin 3\,p\,t\Big\} \sin \phi$$

$$- \Big\{[0.424 - \frac{3}{2}(0.25 \times 0.085)] \cos p\,t$$

$$- \frac{2}{3}[0.254 - \frac{3}{2}(0.62 \times 0.085)] \cos 3\,p\,t\Big\} \cos \phi\Bigg]$$

$$e_s = \frac{250}{845} \times \frac{0.8}{8.4} \times 6725\sqrt{2}\,\Big\{\sin \phi \sin p\,t - \cos \phi \cos p\,t\Big\}$$

$$- \frac{250}{845} \times \frac{0.1}{8.4} \times 6725\sqrt{2}\,\Big\{\cos \phi \sin p\,t + \sin \phi \cos p\,t\Big\}$$

Let us approximate $\phi = 10$ deg.

$\sin \phi = 0.1736$ $\cos \phi = 0.9848$

$$e_f = 6725\sqrt{2}\sin p\,t + 572\sqrt{2}\sin 3\,p\,t.$$

$$e_a = -313\sqrt{2}\sin p\,t + 22\sqrt{2}\sin 3\,p\,t.$$

$$-842\sqrt{2}\cos p\,t + 251\sqrt{2}\cos 3\,p\,t.$$

$$e_z = -33\sqrt{2}\sin p\,t - 187\sqrt{2}\cos p\,t.$$

$$-23\sqrt{2}\sin p\,t + \quad 4\sqrt{2}\cos p\,t.$$

Summing up the third harmonics

$$e_3 = 594\sqrt{2}\sin 3\,p\,t + 251\sqrt{2}\cos 3\,p\,t.$$

$$\because\ E_3 = \sqrt{594^2 + 251^2} = 653 \text{ volts.}$$

$$e_3 \text{ leads } e_f \text{ by } \tan^{-1}\frac{251}{594} = 22.9 \text{ deg. (third harmonic).}$$

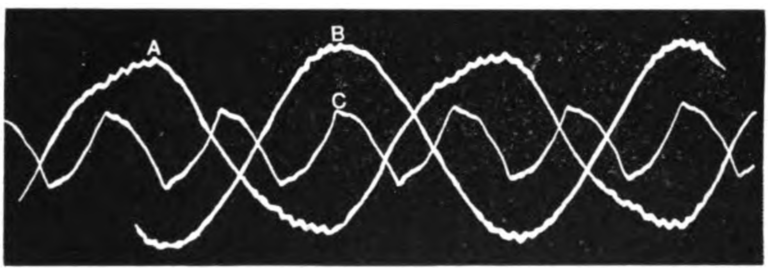


FIG. 14.—Potentials at 500 kw. A = line to neutral; B = line to line; C = neutral to zero

Neglecting the third harmonics

$$e_{PD} = 6356\sqrt{2}\sin p\,t - 1025\sqrt{2}\cos p\,t.$$

$$E_{PD} = \sqrt{6356^2 + 1025^2} = 6435$$

$$e_{pd} \text{ lags } e_f \text{ by } \tan^{-1}\frac{1025}{6356} = 9.3 \text{ deg.}$$

Hence the current is 0.7 deg. lagging instead of being in phase with the potential difference. This approximation is close enough.

Fig. 14 is an oscillograph record taken under approximately the above conditions. From the computation, e_3 leads e_r by

22.9 deg. (triple) while e_{PD} lags behind e_F 9.3 deg. (fundamental). Accordingly, the third harmonic in the loaded machine should lead that in an unloaded one by $22.9+[3\times 9.3] = 50.8$ deg. third harmonic. A comparison of the oscillograph records shows that this is approximately true.

The magnitude of the neutral potential as obtained on test is approximately 10 per cent lower than the calculated value. The excess in the computed potential is probably due to the assumption that the magnetic susceptibility is zero at the interpolar axes. Reference to the flux wave of armature reaction by a current in phase with the excitation e.m.f. (Fig. 3) will show that with a reasonably large susceptibility between the poles the third harmonic will be smaller.

If it be desired to synchronize another machine, it will be brought up to speed with its no-load wave in phase with the potential difference of the first machine. Its potential is represented by the following equation:

$$e = 6356\sqrt{2}\sin p\,t - 1025\sqrt{2}\cos p\,t.$$

$$+\cos 27.9^\circ \times 572\sqrt{2}\sin 3\,p\,t - \sin 27.9^\circ\times 572\sqrt{2}\cos 3\,pt.$$

The third harmonic reduces to

$$506\sqrt{2}\sin 3\,p\,t - 268\sqrt{2}\cos 3\,p\,t$$

while that of the first machine is

$$594\sqrt{2}\sin 3\,p\,t + 251\sqrt{2}\cos 3\,p\,t$$

There will be a resultant potential between the neutrals of these two machines equal to the difference between their third harmonics or

$$88\sqrt{2}\sin 3\,p\,t + 519\sqrt{2}\cos 3\,p\,t$$

$$= 526 \text{ root-mean-square volts}$$

If the neutrals are connected at the same time as the line terminals, a triple frequency current will flow. On account of the fact that the impedance of the circuit is made up of

that of the two machines in series this current will have a final value of $\frac{526}{2\times3.7} = 71$ amperes per phase or $3\times71 = 213$ amperes in the neutral connection.

The first rush of current may reach a magnitude much larger than this. On account of the magnetic lag in the iron the value of the short-circuit current will be limited by the reactance without iron. This is probably not over 20 per cent of the leakage reactance figured above.

Thus the limit of short-circuit current is $\frac{526}{0.20\times2.4} = 1,100$ amperes per phase, or 3,300 amperes in the neutral.

If the machine were carrying a load of twice the magnitude, with the same excitation, we would have the following e.m.fs. Let ϕ be assumed 20 deg.

$$e_f = 6725\sqrt{2}\sin p\,t + 572\sqrt{2}\sin 3\,p\,t.$$

$$e_a = -1233\sqrt{2}\sin p\,t + 87\sqrt{2}\sin 3\,p\,t.$$

$$-1605\sqrt{2}\cos p\,t + 479\sqrt{2}\cos 3\,p\,t$$

$$e_s = -130\sqrt{2}\sin p\,t - 355\sqrt{2}\cos p\,t.$$

$$-49\sqrt{2}\sin p\,t + 16\sqrt{2}\cos p\,t.$$

$$e_3 = 659\sqrt{2}\sin 3\,p\,t + 479\sqrt{2}\cos 3\,p\,t.$$

$$E_3 = \sqrt{659^2 + 479^2} = 821$$

$$e_3 \text{ leads } e_f \text{ by } \tan^{-1}\frac{479}{659} = 36 \text{ deg. (triple).}$$

$$e_{pd} = 5313\sqrt{2}\sin p\,t - 1944\sqrt{2}\cos p\,t \quad -$$

$$E_{PD} = \sqrt{5313^2 + 1944^2} = 5650$$

$$e_{pd} \text{ lags behind } e_f \text{ by } \tan^{-1}\frac{1944}{5313} = 20.1 \text{ deg.}$$

The third harmonic in the loaded machine should lead that in the unloaded machine by $36 + (3 \times 20.1) = 96.1$ deg. Fig. 15 which was taken under conditions approximating the above shows this to be the case. The neutral potential as measured was again about 10 per cent less than the computed value.

The neutral potential of a machine in condition to be synchronized with this one would be.

$$\cos 60.3° \times 572 \sqrt{2} \sin p\,t - \sin 60.3° \times 572 \sqrt{2} \sin p\,t$$

or

$$283 \sqrt{2} \sin p\,t - 496 \sqrt{2} \cos p\,t$$

The resultant potential between the neutrals of the two machines would be $376 \sqrt{2} \sin p\,t + 975 \sqrt{2} \cos p\,t = 1045$ volts.

The first rush of current would be limited to 2200 amperes

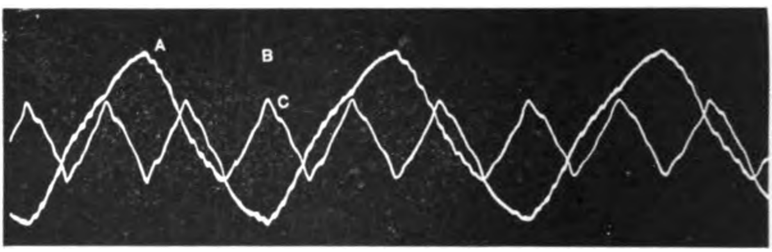


Fig. 15.—Potentials at 9000 kw.

per phase or 6600 amperes in the neutral, while the final current would be 141 amperes per phase or 423 amperes in the neutral.

As soon as the loads and excitations were properly adjusted, this interchange current would become very small.

If this machine had been designed with no open-circuit neutral potential, there would be for 250 amperes load,

$$e_f = 6725 \sqrt{2} \sin p\,t$$

$$e_a = -305 \sqrt{2} \sin p\,t + 62 \sqrt{2} \sin 3\,p\,t$$
$$- 887 \sqrt{2} \cos p\,t + 357 \sqrt{2} \cos 3\,p\,t$$

$$e_z = \text{same as before.}$$

$$E_3 = 363 \text{ volts.}$$

For 500 ampere load.

$$e_f = 6725 \sqrt{2} \sin p\,t$$

$$e_a = -\,1202 \sqrt{2} \sin p\,t + 246 \sqrt{2} \sin 3\,p\,t$$

$$-\,1691 \sqrt{2} \sin p\,t + 682 \sqrt{2} \cos 3\,p\,t$$

e_3 = same as before.
E_3 = 725 volts.

It thus appears that by eliminating the no-load neutral potential, the triple harmonics are considerably reduced, but are still quite large enough to cause trouble.

In the above discussion of synchronizing it is assumed that only one machine is carrying load at the time. If more than one are running, the currents will be increased on account of the parallel paths offered by the several machines. With two machines running they will be increased 33 per cent, and with eight, as is the case in the plants with which I am connected, 78 per cent. It is thus quite evident that trouble might easily be expected in attempting to operate a number of these machines with their neutrals in parallel.

Differences in momentary angular velocities of the prime movers evidence themselves by swings of load which would produce neutral potentials of proportional magnitude. These swings of load are never so great as to cause differences as large as when synchronizing, and furthermore, there is no short circuiting effect.

Differences in excitation in actual practice are very small and will therefore produce but negligible neutral voltages and currents.

The above computations show that machines constructed like the one in question are not suited for operation with their neutrals in parallel. The real difficulty comes when synchronizing. If, however, the neutrals are closed after the terminals are paralleled, the interchange of current will not be dangerous; but unless there is but little swinging of load between them, currents will flow which are liable to be alarming.

How then can alternators be constructed to give no trouble with third harmonics? Comfort A. Adams has shown in the above mentioned paper that if the coil windings are distributed

over 120 deg. of space, there will be generated in them no third harmonic potentials. A winding of this type is quite possible, although the copper efficiency is not quite so great as with the present type.

A second method is as follows: Make the generator with a uniform air-gap, so that the distribution of the armature reaction flux will be of the same form as that of the m.m.f. Cause the field flux distribution to be sinusoidal by distributing the field windings. These windings should be arranged to give approximately a sine wave of m.m.f.

Under these conditions there can be no neutral potential due either to armature reaction or to excitation. It would probably be difficult to produce these conditions exactly, but there should be no difficulty in reducing the third harmonic to a negligible value.

In conclusion then, it appears that alternators as usually designed and built are not suited for parallel operation with their neutrals interconnected. The difficulty is greatly increased during the operation of synchronizing making successful connections more or less uncertain. However, it seems perfectly feasible to build generators which will operate properly and when such machines are needed it should be specified that their neutral potentials as measured by the methods indicated above should not exceed say 1 per cent of the excitation e.m.f.

NOTE

The following paper is to be read at the meeting of the American Institute of Electrical Engineers in **San Francisco, May 5-7, 1910**. This paper is to be presented under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether orally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail

Contributions to the discussion of this paper, if too late to be used at the meeting, should be mailed to **Ralph D. Mershon, 60 Wall St., New York,** and if received prior to June 1 will be treated as if presented at the meeting.

A paper to be presented at the 248th meeting of the American Institute of Electrical Engineers, San Francisco, Cal., May 5-7, 1910.

OBSERVATION OF HARMONICS IN CURRENT AND IN VOLTAGE WAVE SHAPES OF TRANSFORMERS

BY JOHN J. FRANK

INTRODUCTION

Ever since Professor Ryan presented his famous paper on "Transformers" before the Institute, in which attention was called to the lack of symmetry between curves of instantaneous values of current and potential applied to the transformer, numerous writers have discussed the subject from various view points.

One writer on the subject, Mr. Charles K. Huguet, draws the conclusion that the distortion is due entirely to the variations in the permeability of the iron core since hysteresis is essentially unsymmetrical with respect to the magnetization.

Dr. Bedell and Mr. Elbert C. Tuttle, in a more recent paper, present the subject from a purely theoretical view point. In their discussion, they show how complex current waves may be formed by the combination with a fundamental of triple harmonic wave shapes of different amplitude and phase relation. The significance of the resultant wave distortion and of the various hysteresis loops plotted are fully discussed and the following conclusions drawn:

1. When a sinusoidal electromotive force is applied to a coil of wire embracing iron, an alternating current will flow distorted by the presence of a third harmonic.

2. This harmonic is in advance of the fundamental by an angle ψ, which is greater than 30 deg. and less than 180 deg.

3. Considering the maximum of the fundamental as unity, the maximum of this harmonic cannot exceed a definite value of about 0.192 for $\psi = 30$ deg. and 0.333 for $\psi = 180$ deg. (See following table).

LIMITING VALUES OF β AND ψ FOR VARIOUS VALUES OF ϕ

ϕ	β	ψ	ϕ	β	ψ
0°	0.111	0°	40° 6′	0.211	29° 34′
	0.112	5° 41′	45° 14′	0.220	29° 6′
	0.113	7° 59′	46° 34′	0.222	27° 43′
	0.116	11° 8′	57° 44′	0.240	27° 28′
1° 17′	0.120	16° 20′	60° 42′	0.244	27° 1′
1° 45′	0.122	16° 54′	71° 44′	0.260	25° 8′
4° 48′	0.133	22° 30′	76° 48′	0.267	24° 9′
6° 55′	0.140	24° 28′	87° 47′	0.280	21° 56′
8° 34′	0.144	25° 35′	95° 54′	0.289	20° 12′
12° 52′	0.156	27° 40′	107° 16′	0.300	18° 4′
14° 15′	0.160	28° 15′	120° 40′	0.311	14° 34′
17° 37′	0.167	28° 57′	134° 4′	0.320	11° 22′
22° 44′	0.178	29° 41′	143° 35′	0.322	10° 23′
23° 47′	0.180	29° 47′	157° 18′	0.330	5° 43′
30° 39′	0.192	30° 00′	180°	0.333	0°
33° 59′	0.200	29° 56′			

DATA RELATIVE TO COMPLEX CURVES

ϕ	β	α	ψ	I	I′
0°	0.111	0°	0°	1.006	0.8890
2°	0.122	16° 54′	17°	1.007	0.8832
5°	0.135	22° 48′	23°	1.009	0.8833
20°	0.172	29°	29° 30′	1.015	0.9250
30°	0.193	29° 33′	30°	1.019	0.9624
45°	0.220	28° 38′	29° 22′	1.024	0.9868
90°	0.283	19° 36′	20° 30′	1.039	1.1850
135°	0.321	10° 12′	10° 45′	1.050	1.2950
180°	0.333	0°	0°	1.053	1.3330

ϕ is the phase relation of the third harmonic to the fundamental at the origin.
β is the ratio of the maximum ordinates of the fundamental and third harmonic (critical value).
ψ is the phase difference between the maxima of the distorted and fundamental curves.
$90 - \phi$ is lag of fundamental component of current behind e.m.f.
$90 - \alpha$ is lag of equivalent sine current behind e.m.f.
I and I′ are the maxima of the equivalent sine curve and distorted curve, respectively, the maximum value of the fundamental being unity.

4. The angle of hysteretic advance due to the third harmonic cannot exceed 30 degs.

To these may be added also the following conclusions:

5. That if a sinusoidal electromotive force is impressed upon a coil, the magnetic flux threading the coil will likewise be

sinusoidal, and in phase 90 deg. behind the electromotive force, whether the coil embraces iron or not.

6. That the maximum of the current wave must coincide with the maximum of the flux. If the coil embraces iron, the maximum flux coincides with the maximum of the complex wave; if the coil does not embrace iron, the flux coincides with the sinusoidal current wave.

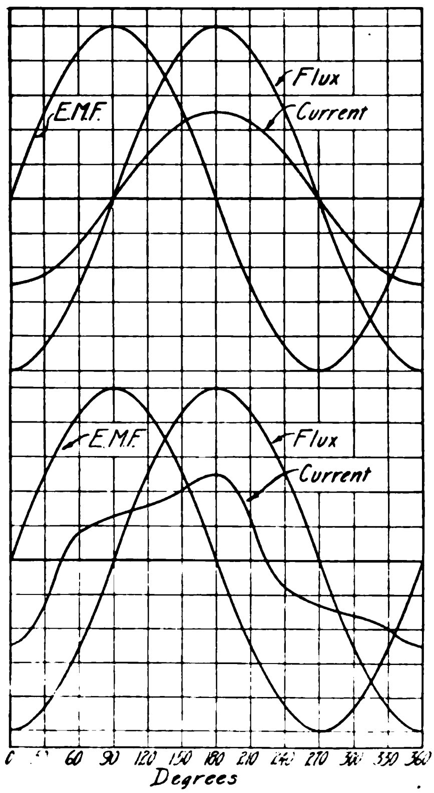


FIG. 1.—Phase relation of current, voltage and flux in a coil not encircling iron

FIG. 1A.—Phase relation of current, voltage and flux in a coil encircling iron

The first four conclusions are drawn from figures given in the preceding tables taken from the paper referred to.

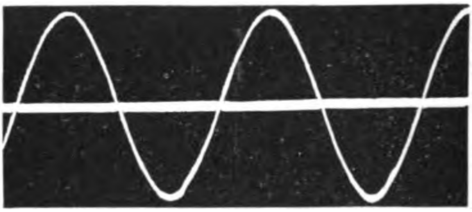
Conclusions 5 and 6 are illustrated in Fig. 1, "Phase relation of current, voltage and flux in a coil not encircling iron", and in Fig. 1 A, " Phase relation of current, voltage and flux in a coil encircling iron."

From the writer's experience, he was led to believe that the value of the third harmonic was not limited to the figures given

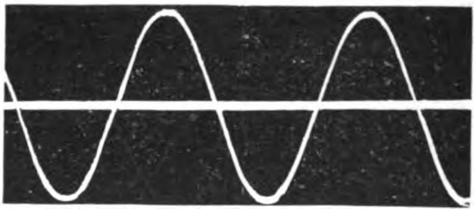
SHEET I.

Oscillograms observed on three single-phase 60-cycle, 150-kw., 4150 volt, Y-connected primary, 480-volt secondary transformers, installed in substation No. 34 of the Rochester Railway and Light Company, Rochester, N. Y.

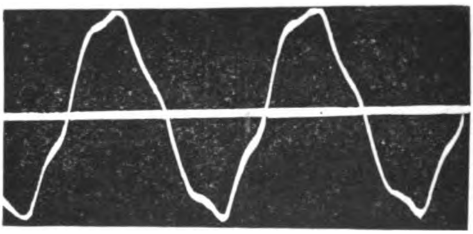
Neutral Isolated—Delta Closed



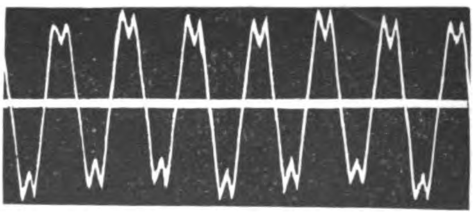
CURVE No. 1
Potential, line to line, 4293 volts.



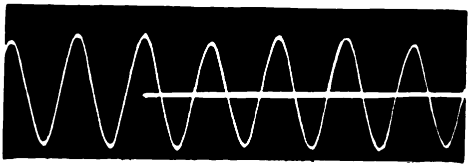
CURVE No. 2
Potential across one transformer (*i.e.*, line to neutral), 2422 volts.



CURVE No. 3
Current in line (*i.e.*, in transformer), 1.2 amperes.



CURVE No. 4
Potential across isolated neutral (*i.e.*, neutral to ground), 125 volts

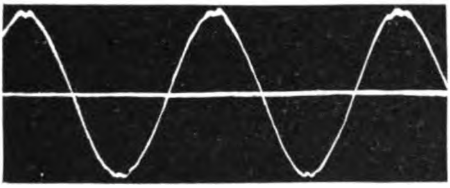


CURVE No. 5
Current in closed secondary delta, 2.35 amperes.

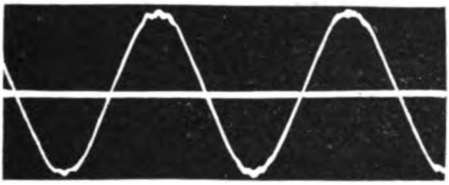
SHEET 2

Oscillograms observed on three single-phase, 60-cycle, 185-kw., 4150-volt Y-connected primary, 480-volt secondary transformers, installed in substation No. 34 of the Rochester Railway & Light Co., Rochester, N. Y.

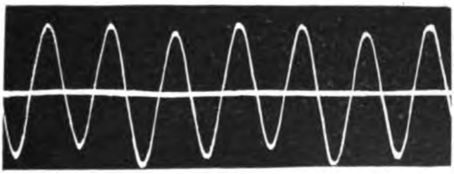
Neutral Connected—Delta Closed



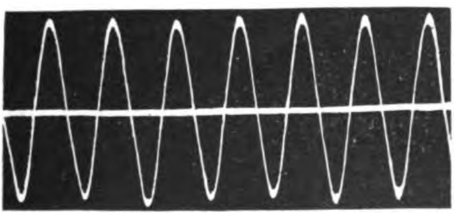
CURVE No. 6
Potential, line to line, 4342 volts.



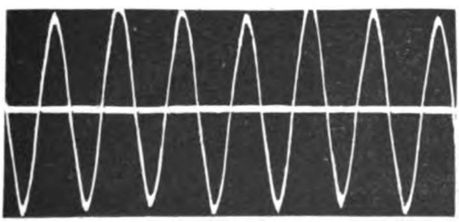
CURVE No. 7
Potential across one transformer, 2540 volts.



CURVE No. 8
Current in line, 39.5 amperes.



CURVE No. 9
Current in connected neutral, 122 amperes.

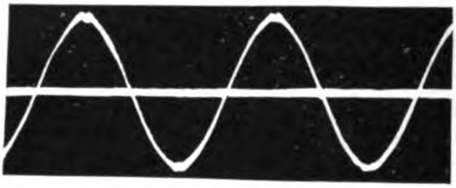


CURVE No. 10
Current in closed secondary delta, 180 amperes.

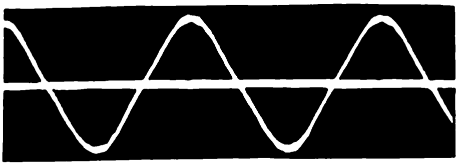
SHEET 3

Oscillograms observed in three single-phase, 60-cycle, 185-kw., 4150-volt Y-connected primary, 480-volt secondary transformers, installed in substation No. 34 of the Rochester Railway & Light Co., Rochester, N. Y

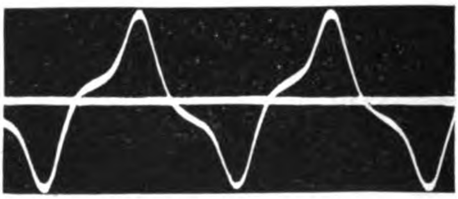
Neutral Connected—Delta Open



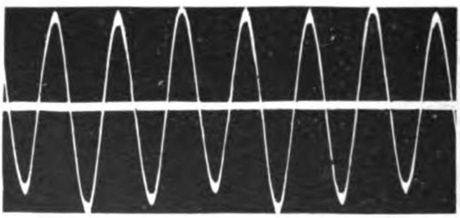
Curve No. 11
Potential, line to line, 4233 volts.



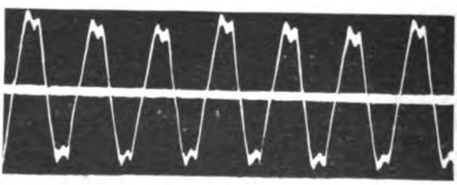
Curve No. 12
Potential across one transformer, 2453 volts.



Curve No. 13
Current in line, 1.65 amperes.



Curve No. 14
Current in connected neutral, 1.45 amperes.

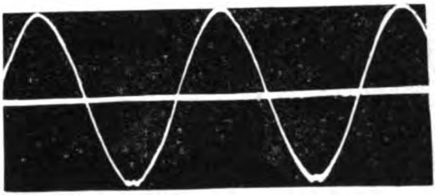


Curve No. 15
Potential across open secondary delta, 73 volts

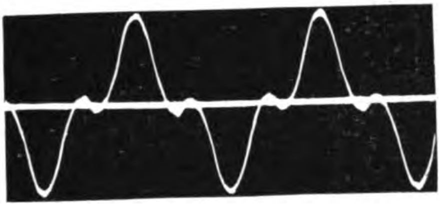
SHEET 4

Oscillograms observed on three-single phase, 60-cycle, 185-kw., 4150-volt Y-connected primary, 480-volt secondary transformers, installed in substation No. 34 of the Rochester Railway & Light Co., Rochester, N. Y.

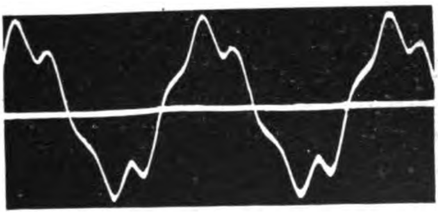
Neutral Isolated—Delta Open



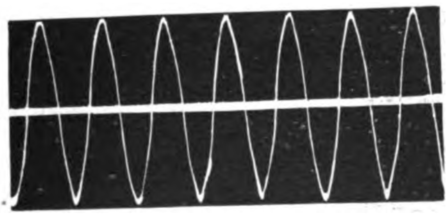
CURVE No. 16
Potential, line to line, 4250 volts.



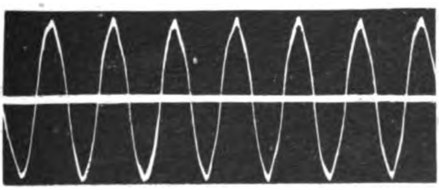
CURVE No. 17
Potential across one transformer, 2705 volts.



CURVE No. 18
Current in line, 1.1 ampere



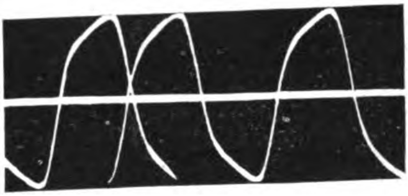
CURVE No. 19
Potential across isolated neutral, 1041 volts.



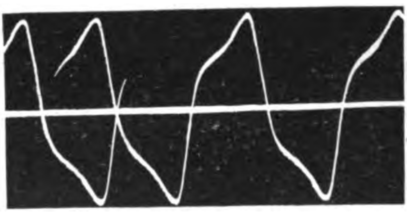
CURVE No. 20
Potential across open secondary delta, 720 volts.

SHEET 5

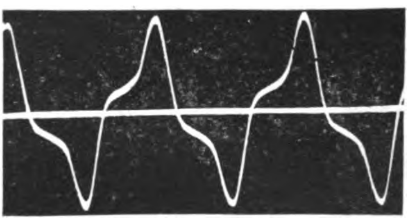
Oscillograms taken on one single-phase, core-type, 25-cycle, 185-kw., 33,000-volt primary, 430-volt secondary transformer, connected single-phase.



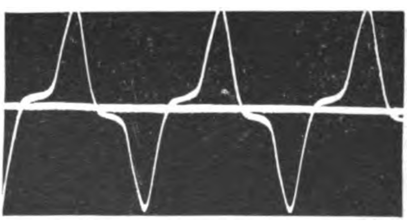
CURVE No. 21
Current at 22.6 kilolines, 3.48 amperes.



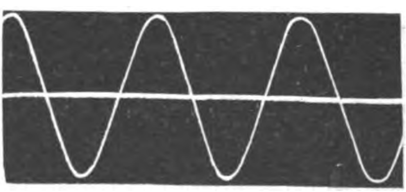
CURVE No. 22
Current at 45.2 kilolines, 5.49 amperes.



CURVE No. 23
Current at 67.9 kololines, 12.5 amperes.



CURVE No. 24
Current at 90.5 kilolines, 35.8 amperes.



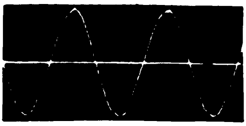
CURVE No. 26
Potential at 90.5 kilolines, 430 volts.

SHEET 6

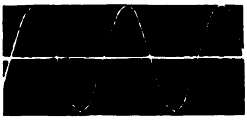
Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt Y-connected primary, 460-volt delta-connected secondary transformer. Density, 106.4 kilolines.

Isolated Neutral—Closed Delta

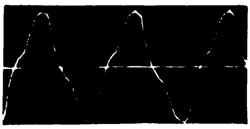
Curve No. 28
Potential, line to line, 2875 volts.



Curve No. 29
Potential across leg 1, (*i.e.*, line 1 to neutral) 1650 volts.

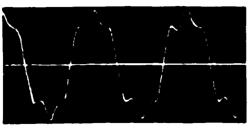


Curve No. 30
Potential across leg 2, 1650 volts.

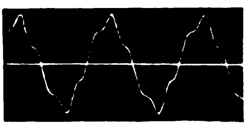


Curve No. 31
Potential across leg 3, 1650 volts.

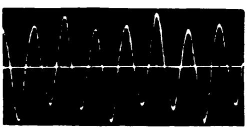
Curve No. 32
Current in line 1, 3.36 amperes.



Curve No. 33
Current in line 2, 2.76 amperes.



Curve No. 34
Current in line 3, 3.0 amperes.



Curve No. 35
Current in closed secondary delta, 2.93 amperes.

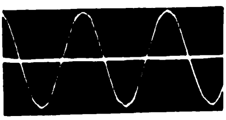
SHEET 7

Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt Y-connected primary, 460-volt delta-connected secondary transformer. Density, 106.4 kilolines.

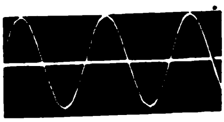
Connected Neutral—Closed Delta

CURVE No. 36
Potential line to line, 2875 volts.

CURVE No. 37
Potential across leg 1, 1652.5 volts. (42.55 kilolines, 662 volts.)

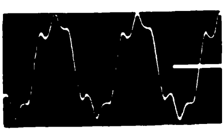


CURVE No. 38
Potential across leg 2, 1652.5 volts.

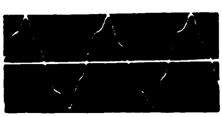


CURVE No. 39
Potential across leg 3, 1652.5 volts.

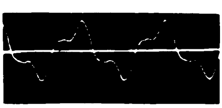
CURVE No. 40
Current in line 1, 3.16 amperes.



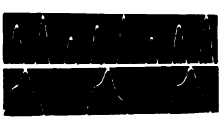
CURVE No. 41
Current in line 2, 2.56 amperes.



CURVE No. 42
Current in line 3, 3.26 amperes.



CURVE No. 43
Current in connected neutral, 0.7 amperes.

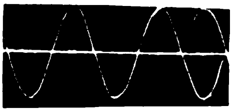


CURVE No. 44
Current in closed secondary delta, 3.0 amperes.

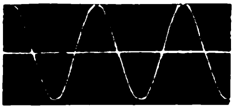
SHEET 8

Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt Y-connected primary, 460-volt delta-connected secondary transformer. Density, 106.4 kilolines.

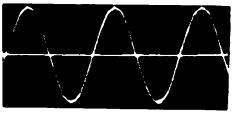
Connected Neutral—Open Delta



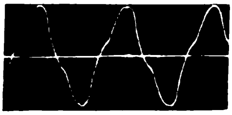
CURVE No. 45
Potential, line to line, 2875 volts.



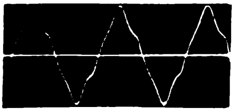
CURVE No. 46
Potential across leg 1, 1652.5 volts.



CURVE No. 47
Potential across leg 2, 1652.5 volts.

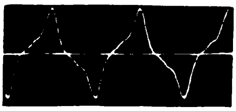


CURVE No. 48
Potential across leg 3, 1652.5 volts.



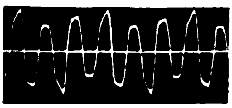
CURVE No. 49
Current in line 1, 2.96 amperes.

CURVE No 50
Current in line 2, 2.76 amperes.



CURVE No. 51
Current in line 3, 3.16 amperes.

CURVE No. 52
Current in connected neutral, 3.25 amperes.

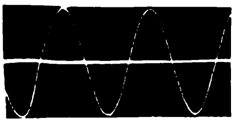


CURVE No. 53
Potential across open secondary delta, 4 volts.

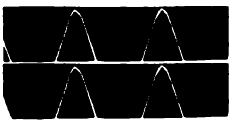
SHEET 9

Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt Y-connected primary, 460-volt delta-connected secondary transformer. Density, 106.4 kilolines.

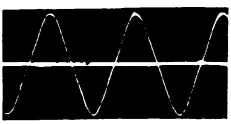
Isolated Neutral—Open Delta



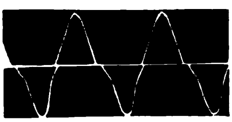
CURVE No. 54
Potential, line to line, 2875 volts.



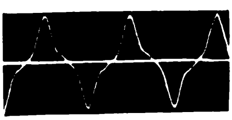
CURVE No. 55
Potential across leg 1, 1655 volts.



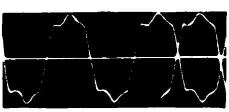
CURVE No. 56
Potential across leg 2, 1655 volts.



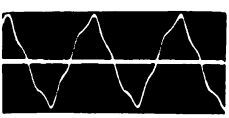
CURVE No. 57
Potential across leg 3, 1655 volts.



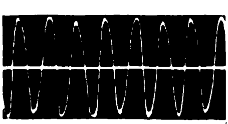
CURVE No. 58
Current in line 1, 3.32 amperes.



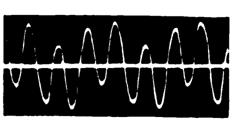
CURVE No. 59
Current in line 2, 2.64 amperes.



CURVE No. 60
Current in line 3, 2.94 amperes.



CURVE No. 61
Potential across isolated neutral, 135 volts.

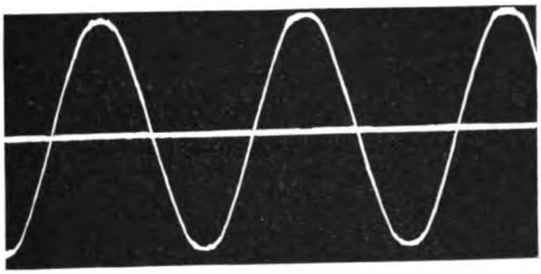


CURVE No. 62
Potential across open secondary delta, 150 volts.

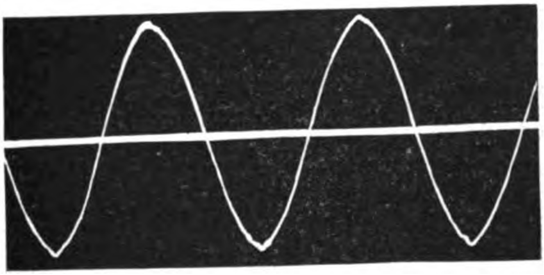
SHEET 10

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt Y-connected secondary transformers.

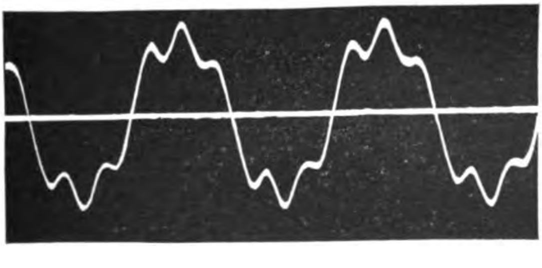
Isolated Neutral—Closed Delta



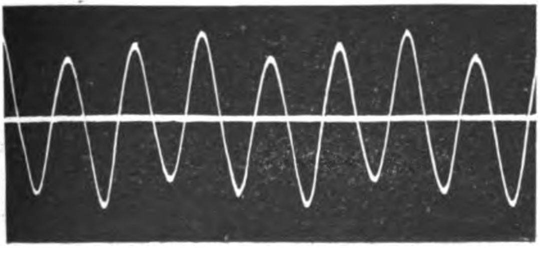
CURVE No. 63
Potential line to line, 795 volts.



CURVE No. 64
Potential across one transformer (*i.e.*, line to neutral), 462.5 volts.



CURVE No. 65
Current in line (*i.e.*, in transformer), 5.81 amperes.

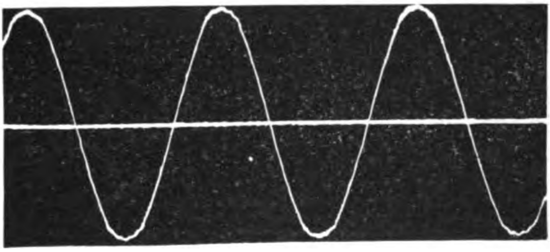


CURVE No. 66
Current in closed primary delta, 0.63 ampere.

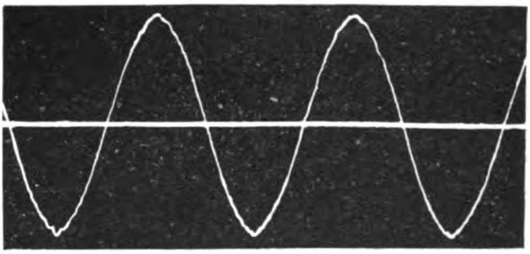
SHEET 11

Oscillograms taken on three single-phase core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt Y-connected secondary transformers.

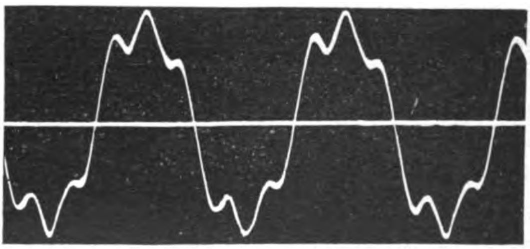
Connected Neutral—Closed Delta



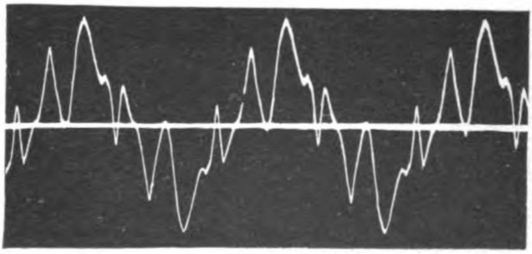
CURVE NO. 67
Potential line to line, 795 volts.



CURVE NO. 68
Potential across one transformer, 462.5 volts.



CURVE NO. 69
Current in line, 3.88 amperes.

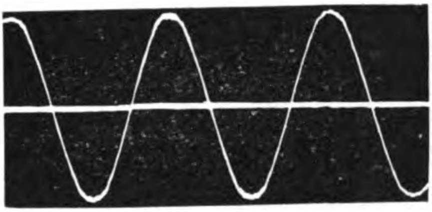


CURVE NO. 70
Current in connected neutral, 0.76 ampere.

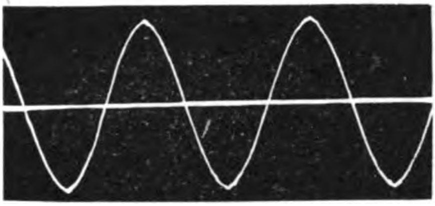
SHEET 12

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt Y-connected secondary transformers.

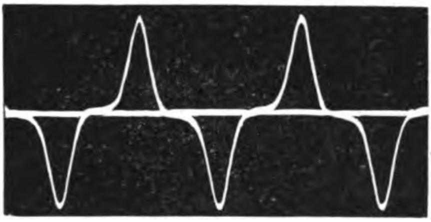
Connected Neutral—Open Delta



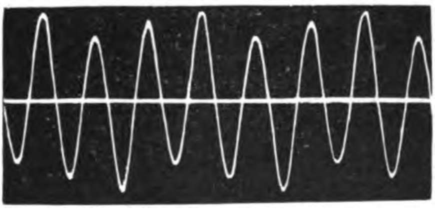
CURVE NO. 71
Potential line to line, 795 volts.



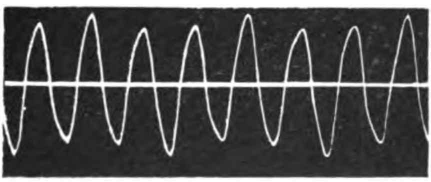
CURVE NO. 72
Potential across one transformer, 462.5 volts.



CURVE NO. 73
Current in line, 5.94 amperes.



CURVE NO. 74
Current in connected neutral, 9.45 amperes.

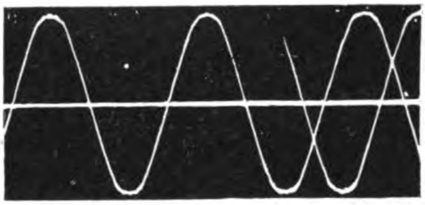


CURVE NO. 75
Potential across open primary delta, 24.5 volts.

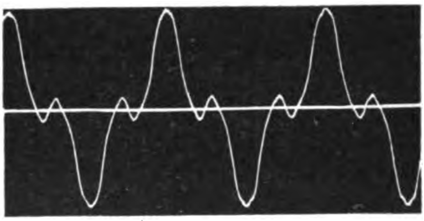
SHEET 13

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt Y-connected secondary transformers.

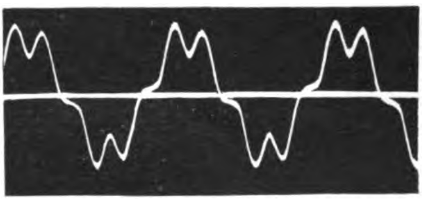
Isolated Neutral—Open Delta



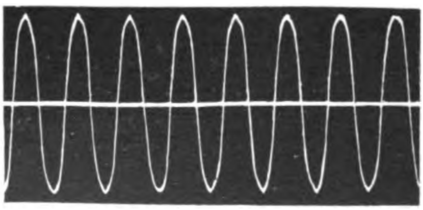
CURVE No. 76
Potential line to line, 795 volts.



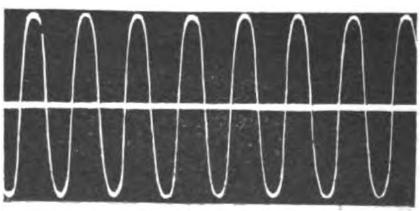
CURVE No. 77
Potential across one transformer, 525 volts.



CURVE No. 78
Current in line, 3.37 amperes.



CURVE No. 79
Potential to isolated neutral, 257 volts.

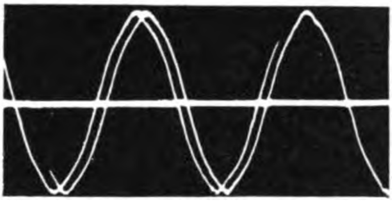


CURVE No. 80
Potential across open primary delta, 3780 volts.

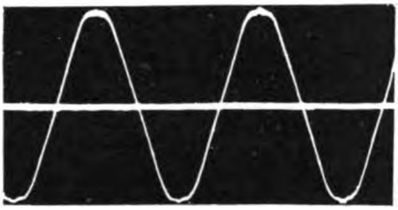
SHEET 14

Oscillograms taken on one three-phase, shell-type, 60-cycle, 330-kw., 13,200-volt delta-connected primary, 430-volt Y-connected secondary transformer.

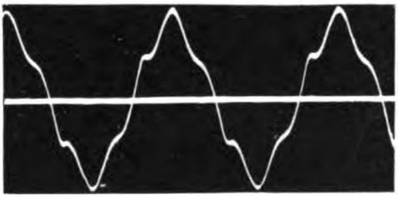
Isolated Neutral—Closed Delta



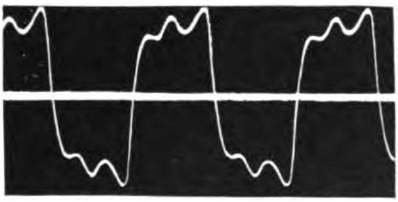
CURVE No. 81
Potential, line to line, 745 volts.



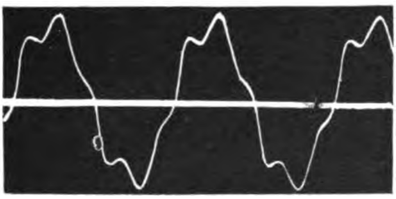
CURVE No. 82
Potential across one leg (i.e. line to neutral), 430 volts.



CURVE No. 83
Current in line 1, 58.8 amperes.



CURVE No. 84
Current in line 2, 44.6 amperes.

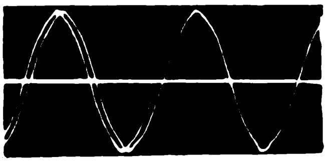


CURVE No. 85
Current in line 3, 57.8 amperes.

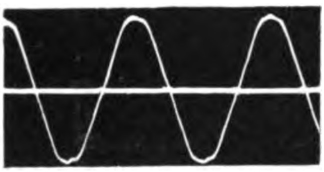
SHEET 15

Oscillograms taken on one three-phase, shell-type, 60-cycle, 330-kw., 13,200-volt delta-connected primary, 430-volt Y-connected secondary transformer.

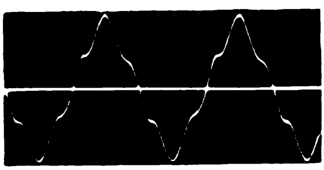
Connected Neutral—Closed Delta



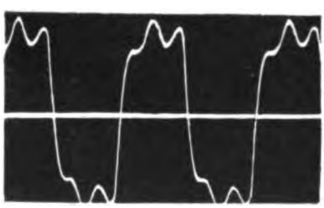
CURVE No. 86
Potential, line to line, 745 volts.



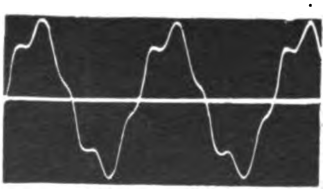
CURVE No. 87
Potential across one leg, 430 volts.



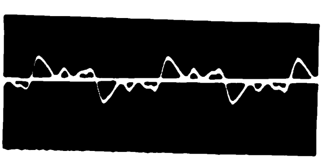
CURVE No. 88
Current in line 1, 60 amperes.



CURVE No. 89
Current in line 2, 45.6 amperes.



CURVE No. 90
Current in line 3, 57.8 amperes.

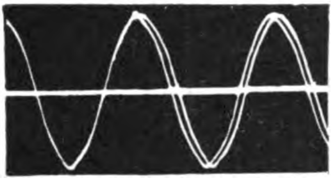


CURVE No. 91
Current in connected neutral, 3.5 amperes.

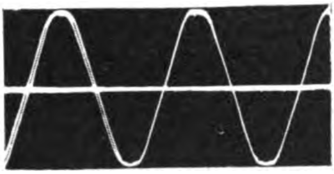
SHEET 16

Oscillograms taken on one three-phase, shell-type, 60-cycle, 330-kw., 13,200-volt delta-connected primary, 430-volt Y-connected secondary. transformer.

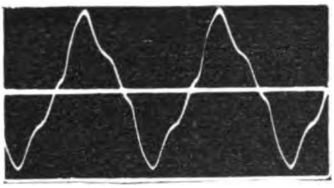
Connected Neutral—Open Delta



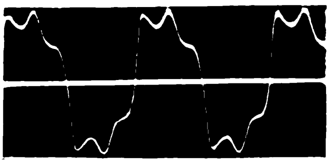
CURVE No. 92
Potential, line to line, 745 volts.



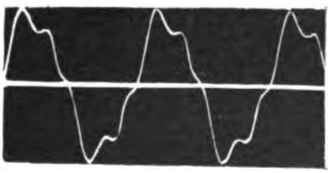
CURVE No. 93
Potential across one leg, 430 volts.



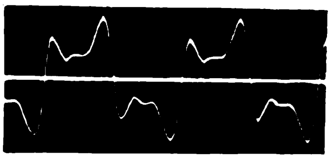
CURVE No. 94
Current in line 1, 64.2 amperes.



CURVE No. 95
Current in line 2, 57.8 amperes.



CURVE No. 96
Current in line 3, 60 amperes.

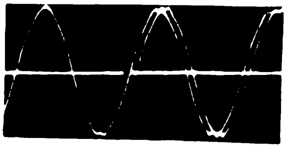


CURVE No. 97
Current in connected neutral, 24.9 amperes.

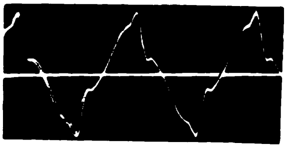
SHEET 17

Oscillograms taken on one three-phase, shell-type, 60-cycle, 430-kw., 13,200-volt delta-connected primary, 430-volt Y-connected secondary transformer.

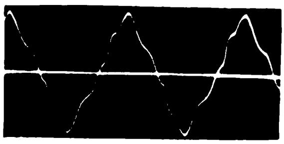
Isolated Neutral—Open Delta



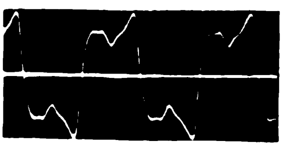
CURVE No. 98
Potential, line to line, 745 volts.



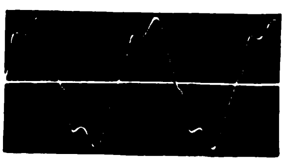
CURVE No. 99
Potential across one leg, 460 volts.



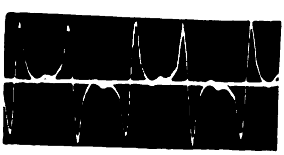
CURVE No. 100
Current in line 1, 53.7 amperes.



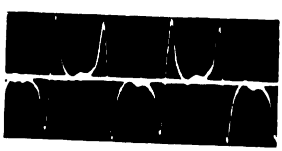
CURVE No. 101
Current in line 2, 36.6 amperes.



CURVE No. 102
Current in line 3, 53.7 amperes.



CURVE No. 103
Potential to isolated neutral, 102.2 volts.

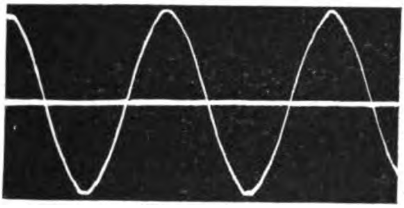


CURVE No. 104
Potential across open primary delta, 9580 volts.

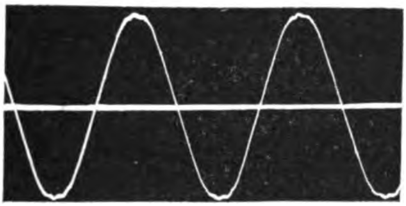
SHEET 18

Oscillograms taken on one three-phase, balanced core-type, 60-cycle, 200-kw., 4600-volt delta-connected primary, 2300-volt Y-connected secondary transformer.

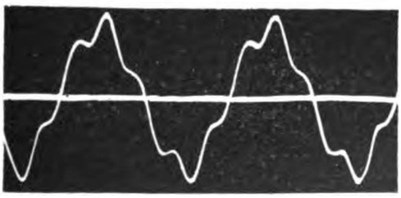
Isolated Neutral—Closed Delta



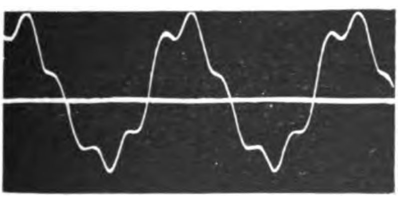
CURVE No. 105
Potential, line to line, 3980 volts.



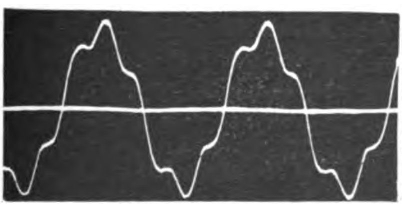
CURVE No. 106
Potential across one leg (*i.e.*, line to neutral), 2275 volts



CURVE No. 107
Current in line 1, 2.0 amperes.



CURVE No. 108
Current in line 2, 1.92 amperes.

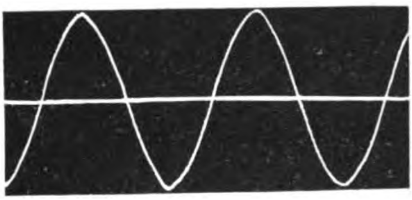


CURVE No. 109
Current in line 3, 2.0 amperes.

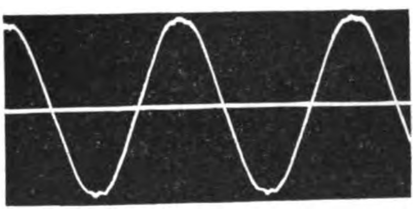
SHEET 19

Oscillograms taken on one three-phase, balanced core-type, 60-cycle, 200-kw., 4600-volt delta-connected primary, 2300-volt Y-connected secondary transformer.

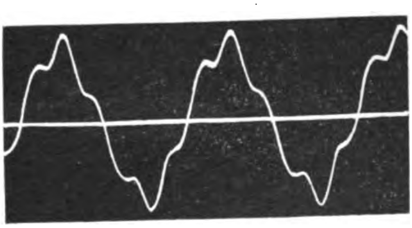
Connected Neutral—Closed Delta



CURVE No. 110
Potential, line to line, 3980 volts.

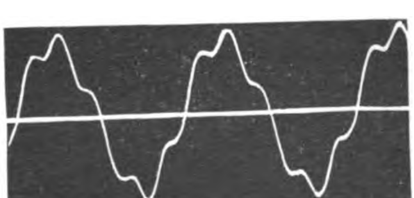


CURVE No. 111
Potential across one leg, 2275 volts.



CURVE No. 112
Current in line 1, 1.97 amperes.

CURVE No. 113
Current in line 2, 1.88 amperes.

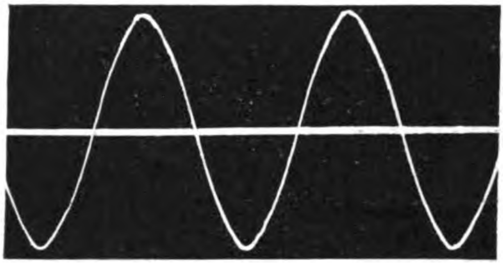


CURVE No. 114
Current in line 3, 1.97 amperes.

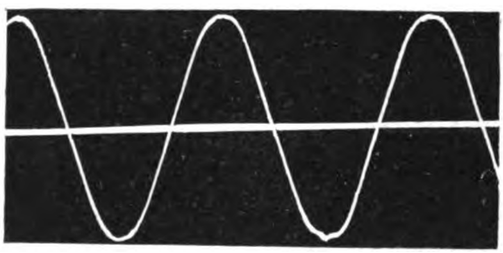
SHEET 20

Oscillograms taken on one three-phase, balanced core-type, 60-cycle, 200-kw., 4600-volt delta-connected primary, 2300-volt Y-connected secondary transformer.

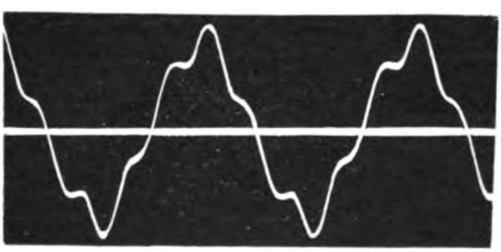
Connected Neutral—Open Delta



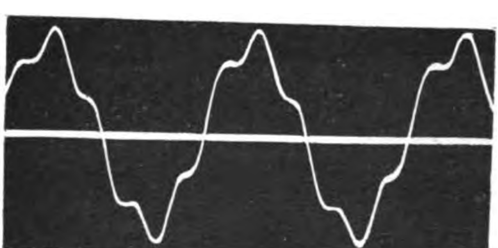
CURVE No. 115
Potential, line to line, 3980 volts.



CURVE No. 116
Potential across one leg, 2275 volts.



CURVE No. 117
Current in line 1, 1.58 amperes.

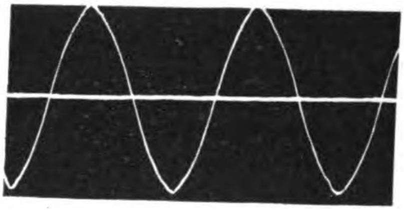


CURVE No. 118
Current in line 3, 1.6 amperes.

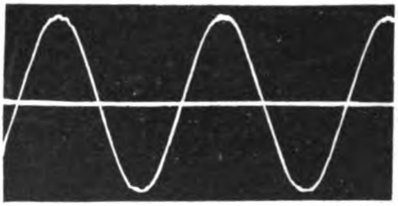
SHEET 21

Oscillograms taken on one three-phase, balanced core-type, 60-cycle, 200-kw., 4600-volt delta-connected primary, 2300-volt Y-connected secondary transformer.

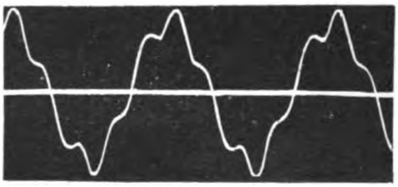
Isolated Neutral—Open Delta



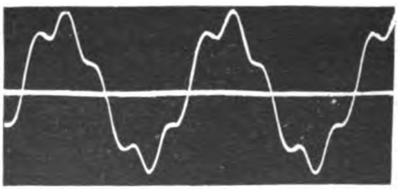
CURVE No. 119
Potential, line to line, 3980 volts.



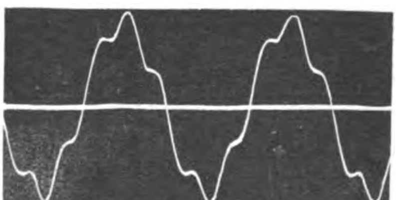
CURVE No. 120
Potential across one leg, 2275 volts.



CURVE No. 121
Current in line 1, 1.82 amperes.



CURVE No. 122
Current in line 2, 1.70 amperes.

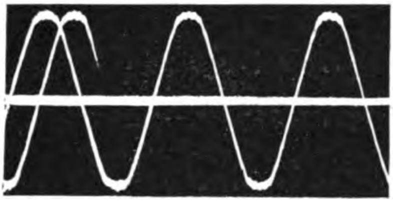


CURVE No. 123
Current in line 3, 1.80 amperes.

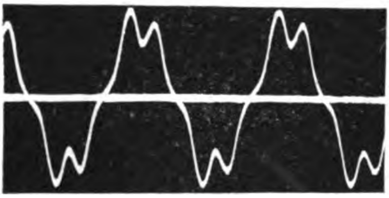
SHEET 22

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt delta-connected secondary.

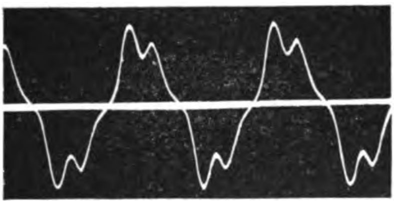
Primary, Closed Delta—Secondary, Closed Delta



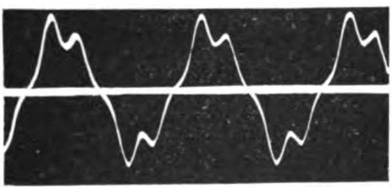
CURVE No. 124
Potential, line to line, 460 volts.



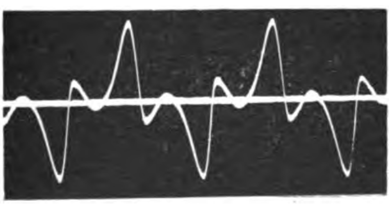
CURVE No. 125
Current in line 1, 11.4 amperes.



CURVE No. 126
Current in line 2, 9.95 amperes.



CURVE No. 127
Current in line 3, 9.7 amperes.

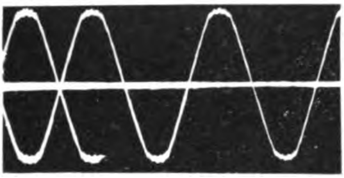


CURVE No. 128
Current in primary delta, 7.1 amperes.

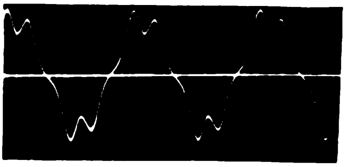
SHEET 23

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt delta-connected secondary.

Primary, Closed Delta—Secondary, Open Delta

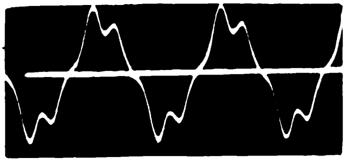


Curve No. 129
Potential, line to line, 460 volts.

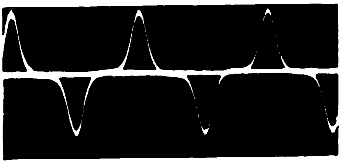


Curve No. 130
Current in line 1, 11.4 amperes.

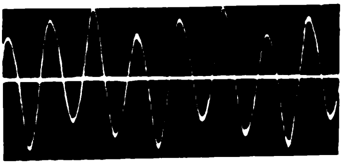
Curve No. 131
Current in line 2, 9.95 amperes.



Curve No. 132
Current in line 3, 9.7 amperes.



Curve No. 133
Current in primary delta, 7.1 amperes.

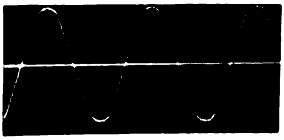


Curve No. 134
Potential across open secondary delta, 4.7 volts.

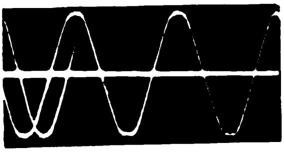
SHEET 24

Oscillograms taken on three single-phase, core-type, 25-cycle, 25-kw., 2300-volt delta-connected primary, 460-volt delta-connected secondary.

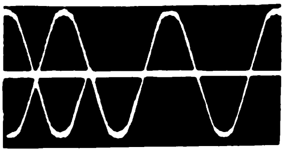
Primary, Open Delta—Secondary, Open Delta



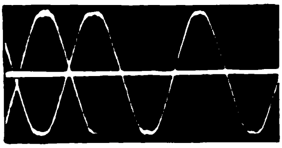
CURVE NO. 135
Potential across one leg of primary 2280 volts.



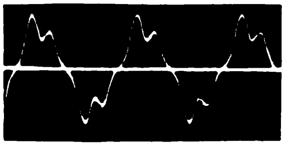
CURVE NO. 136
Potential, line 1 to line 3, 460 volts.



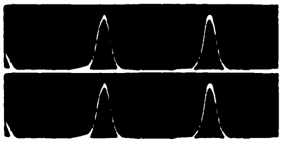
CURVE NO. 137
Potential, line 1 to line 2, 460 volts.



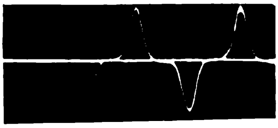
CURVE NO. 138
Potential, line 2 to line 3, 460 volts.



CURVE NO. 139
Current in line 1, 10.0 amperes.



CURVE NO. 140
Current in line 2, 7.5 amperes.

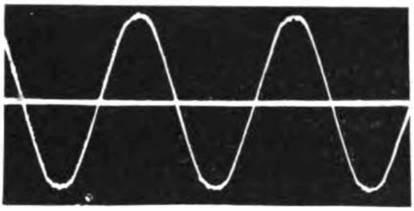


CURVE NO. 141
Current in line 3, 5.7 amperes.

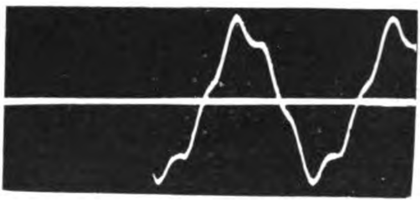
Sheet 25

Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt delta-connected primary, 460-volt delta-connected secondary.

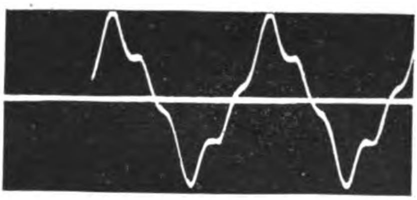
Primary, Closed Delta—Secondary, Closed Delta



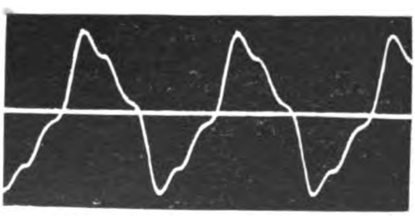
Curve No. 142
Potential, line to line, 430 volts.



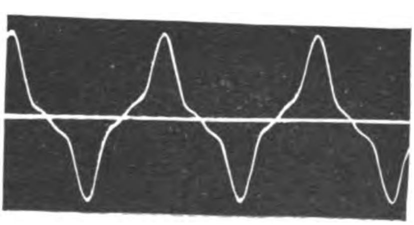
Curve No. 143
Current in line 1, 5.0 amperes.



Curve No. 144
Current in line 2, 4.05 amperes.



Curve No. 145
Current in line 3, 3.6 amperes.

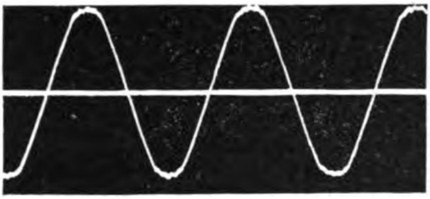


Curve No. 146
Current in primary delta, 2.98 amperes.

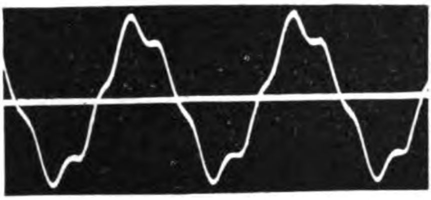
SHEET 26

Oscillograms taken on one three-phase, core-type, 25-cycle, 40-kw., 2300-volt delta-connected primary, 460-volt delta-connected secondary.

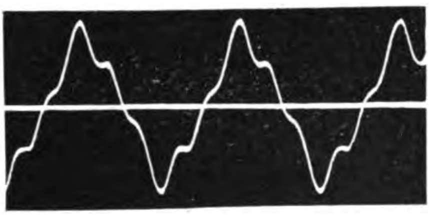
Primary, Closed Delta—Secondary, Open Delta



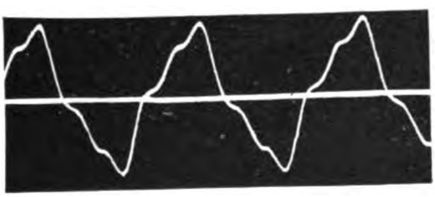
CURVE No. 147
Potential, line to line, 430 volts.



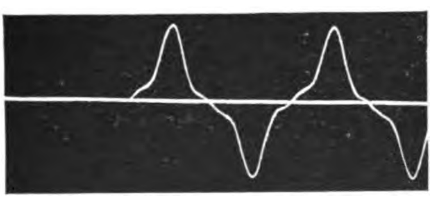
CURVE No. 148
Current in line 1, 5.0 amperes.



CURVE No. 149
Current in line 2, 3.6 amperes.



CURVE No. 150
Current in line 3, 4.05 amperes.

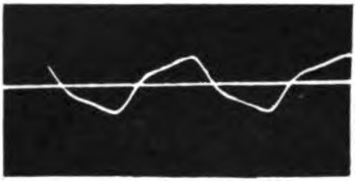


CURVE No. 151
Current in primary delta, 2.98 amperes.

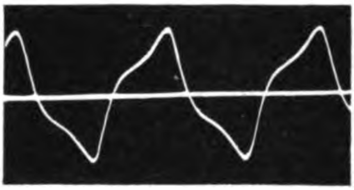
SHEET 27

Oscillograms taken on one single-phase, core-type, 25-cycle, 25-kw. 2300-volt primary, 460-volt secondary transformer.

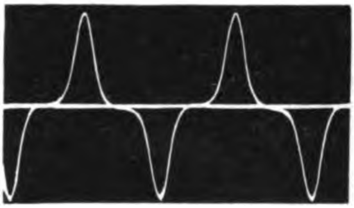
Single Phase



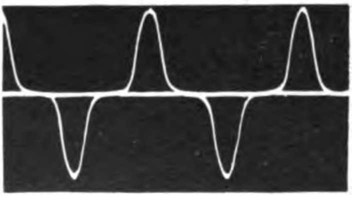
Curve No. 152
Potential at 22.5 kilolines, 115 volts.



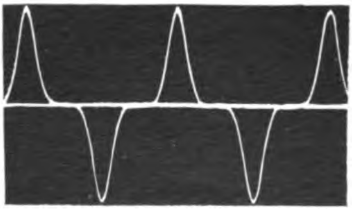
Curve No. 153
Potential at 45.0 kilolines, 230 volts.



Curve No. 154
Potential at 90 kilolines, 460 volts



Curve No. 155
Potential at 112.5 kilolines, 575 volts.

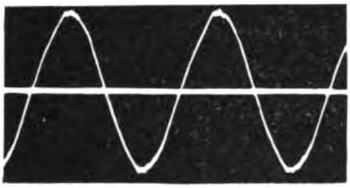


Curve No. 156
Potential at 135 kilolines, 675 volts.

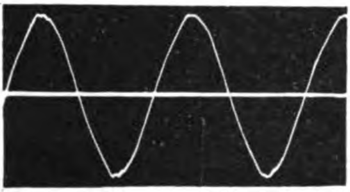
SHEET 27A

Oscillograms taken on one single-phase, core-type, 25-cycle, 25-kw., 2300-volt primary, 460-volt secondary transformer.

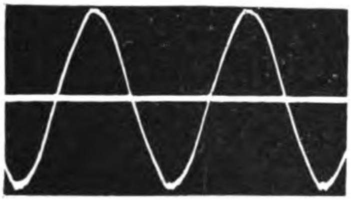
Single Phase



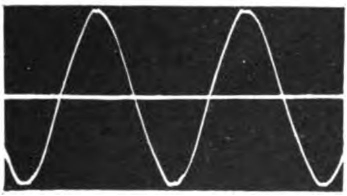
CURVE No. 157
Current at 22.5 kilolines, 0.402 amperes.



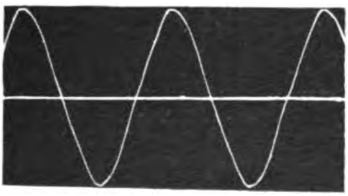
CURVE No. 158
Current at 45.0 kilolines, 0.75 amperes.



CURVE No. 159
Current at 90 kilolines, 6.05 amperes.



CURVE No. 160
Current at 112.5 kilolines, 27.2 amperes.

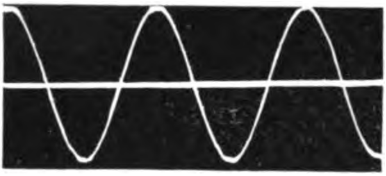


CURVE No. 161
Current at 135 kilolines, 113.4 amperes.

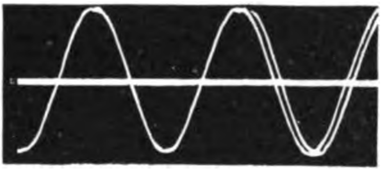
SHEET 28

Oscillograms taken on one alternator at Station No. 3, Rochester Railway and Light Co., Rochester, N. Y. Connected neutral, 24 poles, 2100-kw., 300 rev. per min., 4150 volts.

Load 1500 kw.

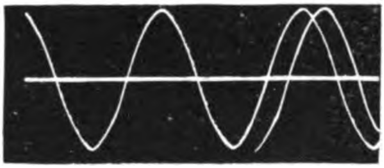


CURVE NO. 162
Potential wave, line *A* to line *B*, 4440 volts.

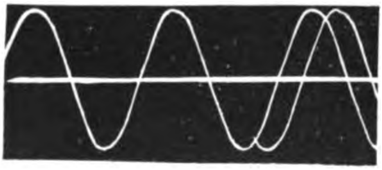


CURVE NO. 163
Potential wave, neutral to line *C*, 2560 volts.

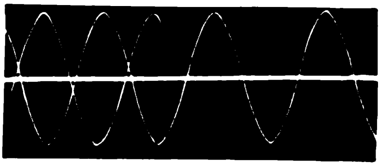
Isolated neutral, 80 poles, 1360 kw., 90 rev. per min., 2500 volts



CURVE NO. 164
Potential wave, line *A* to line *B* (no load), 4357 volts.

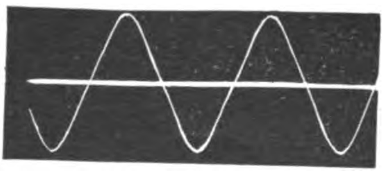


CURVE NO. 165
Potential wave, neutral to line *A* (no load), 2455 volts.



CURVE NO. 166
Potential wave, neutral to line *C* (no load), 2455 volts.

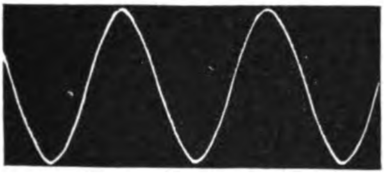
Isolated neutral, 10 poles, 3000 kw., 720 rev. per min., 4150 volts



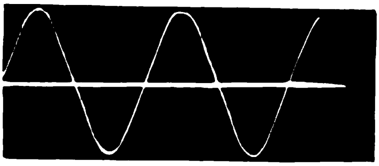
CURVE NO. 167
Potential wave, neutral to line *C* (no load), 2487 volts.

SHEET 29

Oscillograms taken on one alternator at Station No. 5, Rochester Railway and Light Co., Rochester, N. Y. Isolated neutral, 22 poles, 1200-kw., 327 rev. per min., 4150 volts.

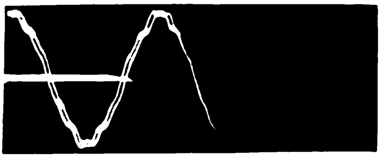


CURVE No. 168
Potential wave, line to line (no load), 4230 volts.

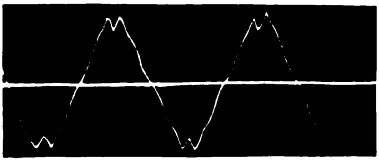


CURVE No. 169
Potential wave, neutral to line (no load), 2718 volts.

Isolated neutral, 16 poles, 350 kw., 450 rev. per min., 2500 volts

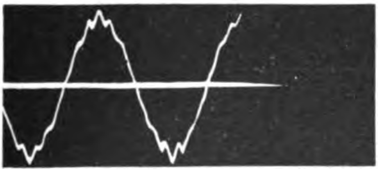


CURVE No. 170
Potential wave, line to line (no load), 4457 volts.

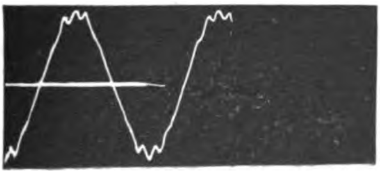


CURVE No. 171
Potential wave, neutral to line (no load), 2540 volts.

Isolated neutral, 24 poles, 530 kw., 300 rev. per min., 4150 volts. Frequency Changer



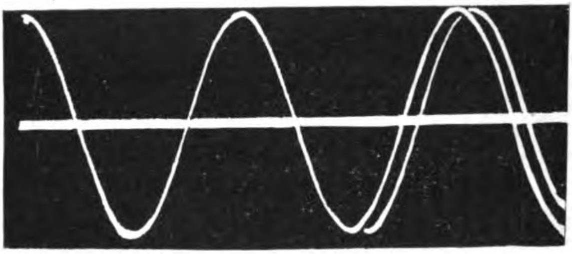
CURVE No. 172
Potential wave, line to line (no load), 4083 volts.



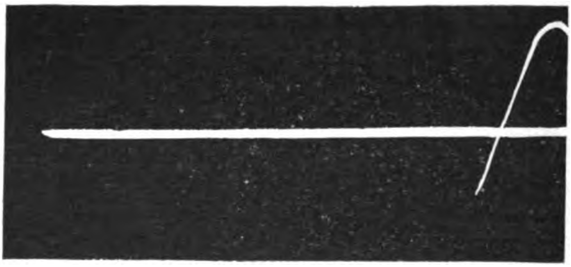
CURVE No. 173
Potential wave, neutral to line (no load), 2277 volts.

SHEET 30

Oscillograms taken on one alternator at Station No. 15, Rochester Railway and Light Co., Rochester, N. Y. Connected neutral, 36 poles, 500 kw., 200 rev. per min., 4150 volts.

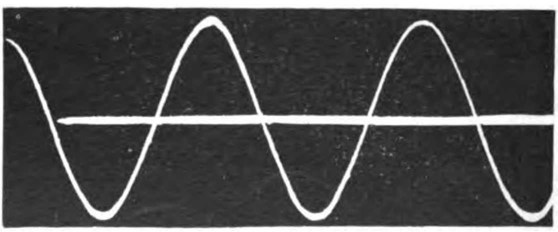


CURVE No. 174
Potential wave, line *A* to line *B* (no load), 4,373 volts.

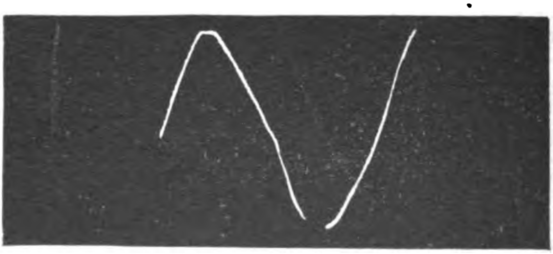


CURVE No. 175
Potential wave, neutral to line *C* (no load), 2,400 volts.

Feeders at Station No. 34, Rochester Railway and Light Co., Rochester, N.Y. Transformers disconnected



CURVE No. 176
Potential wave, line to line (no load), 4313 volts.



CURVE No. 177
Potential wave, ground to line (load, 500 kw.), synchronous motor and 450-kw. transformer, 2473 volts.

in the above tables, as these conclusions were drawn without consideration of any harmonics higher than the third which might be present in the wave shape of the exciting current of the average commercial transformer. A series of tests and investigations with the oscillograph was, therefore, undertaken to check this opinion on the subject and at the same time to make evident, if possible, that the investigation and discussion of current and potential wave shapes has scientific value not only from a theoretical view point, but has great practical value from the operating standpoint as well. It has great bearing on the successful operation of every large alternating current distributing system and must be so considered, as a

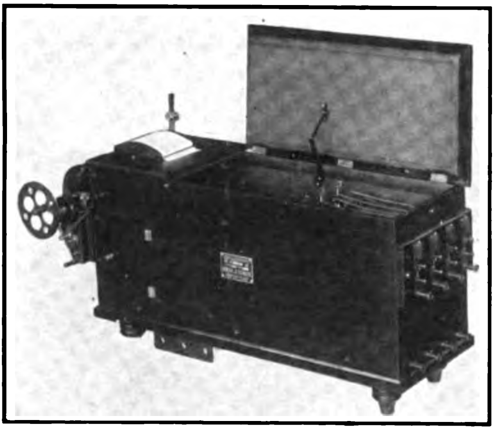


FIG. 2.—Oscillogram showing photographic and tracing attachment

disregard of the importance or effect of this distortion may lead to dangerous conditions and disastrous results.

Oscillograms of current and potential wave shapes discussed in the succeeding pages of the paper were taken by an oscillograph similar to that described in the paper by L. T. Robinson, TRANSACTIONS of the American Institute of Electrical Engineers, Vol. 24, and shown in Figs. 2 and 3.

As the two half cycles of the oscillograph curve are symmetrical, it is necessary for the analysis and subsequent discussion to consider only the first half cycle, which part on an enlarged scale has been transferred by means of a dividing engine to coördinate paper, and resolved into its component curves, of

the first, third and fifth, etc., frequencies, by the method described by Professor S. P. Thompson in his book on Dynamo Electric Machinery, Vol. II, and which is given in the appendix to this paper, together with a complete analysis of curve No. 78, Sheet 13, the analysis of which is shown in Fig. 17. The accuracy of the method has been tested by comparing the original complex wave with the complex wave formed by combining the several component curves. In every case, the two complex waves are almost identical.

Plotting of Hysteresis Loop

As a basis for discussion, and as representative of a size and voltage commonly found in practice, a 25-cycle, 185-kw.,

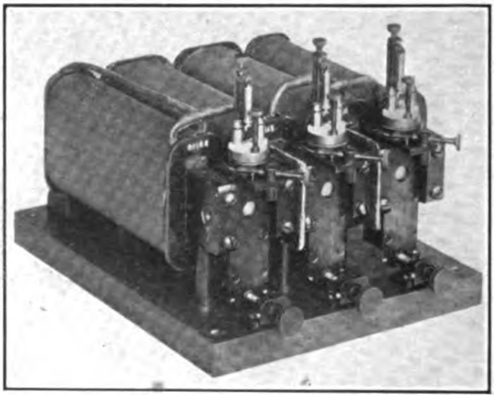
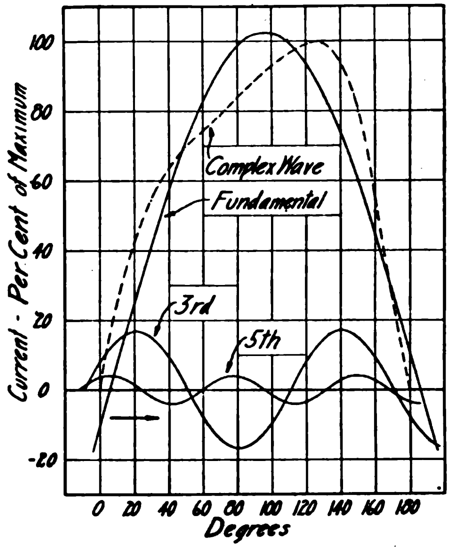


Fig. 3.—Oscillograph galvanometer

33,000-volt primary, 430-volt secondary transformer was selected, on which oscillograms of exciting current were taken with strictly sinusoidal potential applied. Sheet 5 shows the oscillograms corresponding to different densities. The analysis of these curves, given in Figs. 4, 5, 6 and 7, show the characteristic distortion due to the presence of the harmonics. In these figures, the curves marked "complex wave" correspond to the oscillograms on Sheet 5. These complex waves, by the method previously referred to, have been resolved into their component sine waves. The following table gives the values of the maxima of these several curves in terms of the maximum of the complex and also in terms of the maximum of the fundamental wave.



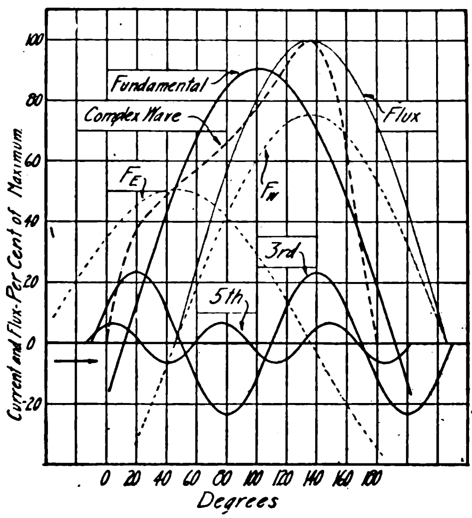
Max. complex wave = 100

R_1 = 102.6 ϕ_1 = − 6° 16′

R_3 = 17.0 ϕ_3 = 27° 9′ 25% excitation

R_5 = 4.0 ϕ_5 = 58° 38′

Fig. 4.—Analysis of oscillogram No. 21 Sheet No. 5



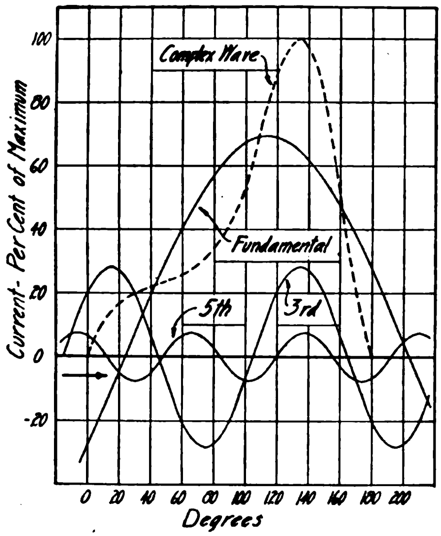
Max. complex wave = 100

R_1 = 90.7 ϕ_1 = −11° 52′

R_3 = 23.3 ϕ_3 = 30° 43′ 50% excitation

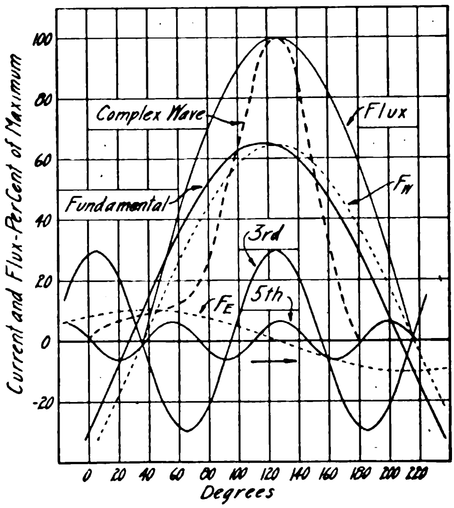
R_5 = 6.6 ϕ_5 = 66° 52′

Fig. 5.—Analysis of oscillogram No. 22 Sheet No. 5



Max. complex wave = 100
R_1 = 69.4 ϕ_1 = −23° 50′ 75 per cent excitation
R_3 = 28.2 ϕ_3 = 45° 30′
R_5 = 7.7 ϕ_5 = 120° 0′

FIG. 6.—Analysis of oscillogram No. 23 Sheet No. 5



Max. complex wave = 100
R_1 = 65.0 ϕ_1 = −27° 1′ 100 per cent excitation
R_3 = 29.9 ϕ_3 = 73° 55′
R_5 = 6.2 ϕ_5 = 170° 24′

FIG. 7.—Analysis of oscillogram No. 24 Sheet No. 5

TABLE I.

DATA RELATIVE TO CURVE IN FIGS. 4–7

25-cycle, 185-kw., 33,000-volt primary, 430-volt secondary, single-phase transformer

	Relative values of maxima in terms of complex wave				Relative value of maxima in terms of fundamental wave							
Density per sq. in. kilolines	Complex wave per cent	Fundamental per cent	Third harmonic per cent	Fifth harmonic per cent	Fundamental per cent	Third harmonic per cent	Fifth harmonic per cent	Complex wave per cent	Amperes effective	Core loss watts	Angle of advance of 3d over fund in terms of fundamentals	Angle of hysteretic advance
22.6	100	102.6	17	4.0	100	16.6	3.9	97.5	3.48	233	15°	31°
45.25	100	90.7	23.3	6.6	100	25.5	7.3	110.0	5.49	730	22°	34°
61.9	100	69.2	28.8	7.7	100	41.6	11.1	144.5	12.5	1488	39°	21°
90.5	100	65.0	29.9	6.2	100	46	9.6	154	35.8	2575	52°	9°

Fig. 8 gives the square root of the mean square value of exciting current and core loss on this transformer at different densities.

It will be seen that these figures do not bear out the conclusion drawn by Dr. Bedell and Mr. Tuttle. It will be noted that ϕ, the angle between the third and the fundamental at the origin, is not limited to values between 30 degs. and 180 degs., but may vary between greater ranges of value. The angle of hysteretic advance, or the angle between the maximum of the fundamental and the maximum flux, may be larger than 30 degs., as shown in Fig. 5. No doubt the explanation for this is due to the fact that in the former discussion, only the fundamental and the third harmonic were considered as forming the complex wave, whereas in the present instance, it is shown that at least the fifth, in addition to the fundamental and the third, is found in the complex waves.

From these curves and the table given above, the conclusion may be drawn that the amplitude of the third harmonic increases with the density in the core, the limiting value being dependent, to a certain extent, on the value of the other higher harmonics also present in the current wave.

In Figs. 5 and 7, curves have been added to represent the flux and, in accordance with conclusion 6, page 667, the maximum of the flux is shown in phase with the maximum of the complex wave. In Fig. 5, the maximum of this flux wave represents a

density equal to 45.2 kilolines per square inch, while in Fig. 7, it represents a density of 90.5 kilolines per square inch.

For a further discussion of the curves, the fundamental wave has been resolved into two sinusoidal curves whose maxima are 90 deg. apart; one F_e in phase with the voltage, and one F_w in phase with the flux. The former, in phase with the voltage, represents energy given to the core; that is, hysteretic loss. The latter, 90 deg. out of phase with the voltage and consequently in phase with the flux, represents no power; that is, wattless or that part of the current required merely to magnetize the core. The complex wave, *i.e.*, the oscillogram, has, therefore, been resolved into four component parts; two of fundamental fre-

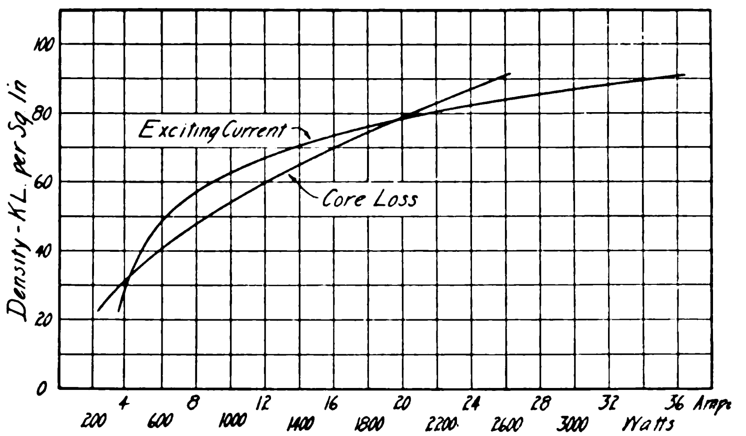


FIG. 8.—Curve of exciting current and losses single-phase core type 25-cycle, 185-kw. 33,000-volt primary, 430-volt secondary transformer.

quency—one, F_w in phase with the flux, the other, F_e in phase with the voltage—and one curve of three times fundamental frequency and one curve of five times fundamental frequency.

Using a system of rectangular coördinates, and plotting loops with these various curves in conjunction with the curve of flux, some interesting results follow:

1. Using the complex current and the sinusoidal flux wave, the well-known hysteresis loop may be plotted whose area is equal to, or rather represents, the energy given to the core for any particular induction. In Figs. 9 and 12, the loop marked $L\,C$, is shown corresponding to a density in the core of 45.2 kilolines and 90.5 kilolines per sq. in. respectively.

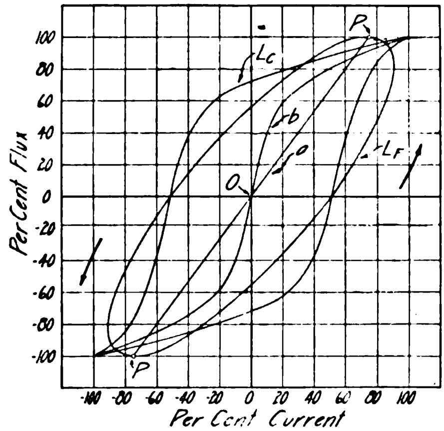


FIG. 9.—Loops plotted from oscillogram No. 21 sheet No. 5 and oscillogram No. 26 Sheet No. 5

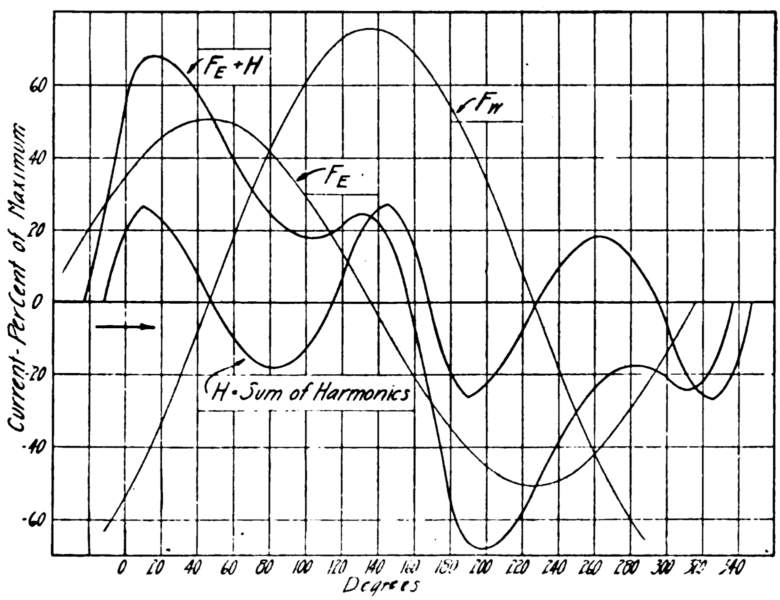


FIG. 10.—Curves obtained from oscillogram No. 22 Sheet No. 5 and oscillogram No. 26 sheet No. 5

2. Using the fundamental component of the current wave instead of the complex wave, *i.e.*, the complex wave minus the higher harmonics, and the sinusoidal flux curve, an elliptical loop, marked $L\ F$, results, of the same area as the distorted loop. This indicates that the same energy is given to the core. The conclusion to be drawn is, that with sinusoidal potential applied, the higher harmonics in the current wave are not produced by, or do not produce, the energy loss in the core.

3. Using the wattless component F_w of the fundamental and

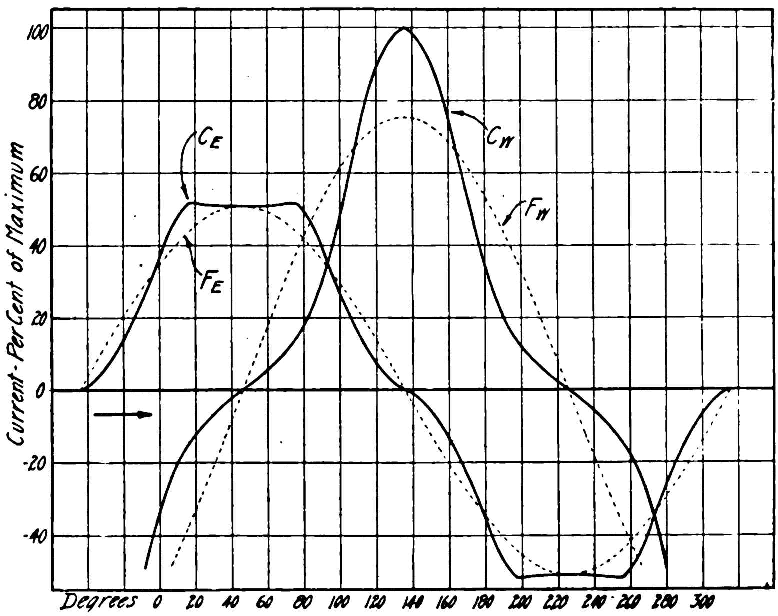


FIG. 11.—Curves obtained from oscillogram No. 22 sheet No. 5 and oscillogram No. 26 sheet No. 5

the sinusoidal flux wave, the straight line curve *a*, Fig. 9, is obtained, passing through zero and intersecting the ellipse at the point *P*. Since the wattless component of the current is used in conjunction with the flux curve, the figure should enclose no area, as it represents no loss. It should be noted that the location or relative position of this line *a* is determined by the magnetizing component of the fundamental of the exciting current. The point *P*, *i.e.*, the intersection of the straight line *a* with the ellipse, may be predetermined by using the amplitude of the

wattless component of the fundamental as abscissa, plotted against the maximum of the flux as an ordinate. This point P and zero determine the direction of the line. If the magnetizing component of the fundamental were small compared with the energy component, the angle made by this line a with the vertical axis would be small, and were this component large, the angle made by the line a with the vertical would be large. Should it be possible for this component to equal zero, the line a would be vertical and would coincide with the vertical axis of ordinates.

4. Uniting the energy component of the fundamental with the higher harmonics, the curve shown in Figs. 10 and 13, marked

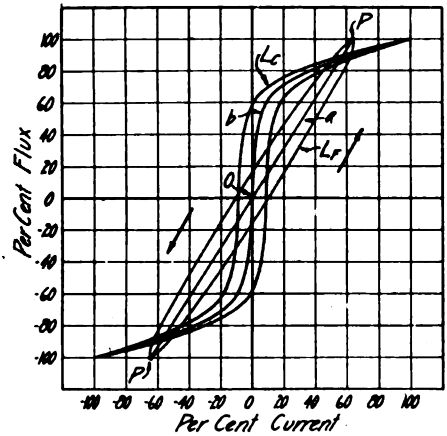


FIG. 12.—Curves plotted from oscillogram No. 24 sheet No. 5 and oscillogram No 26 sheet No. 5

$F_e + H$ follows. F_e is the energy component of the fundamental, as shown in Figs. 5 and 7, and curve H is the sum of the harmonics; *i.e.*, the complex wave minus the fundamental. Using ordinates of this curve $F_e + H$ as abscissa, and line a as an axis, the original hysteresis loop $L\,c$, Fig. 9 will result. The ordinates of this curve $F_e + H$, Fig. 10, above the zero line are plotted to the right of line a, Fig. 9, and the ordinates of $F_e + H$, Fig. 10, below the zero line are plotted to the left of line a, Fig. 9. Since the sinusoidal flux wave has again been combined with the energy, wattless, and harmonic components of the current, the resultant figure should be the hysteresis loop originally plotted.

5. Using the energy component F_e of the fundamental, and

the sinusoidal flux wave, an ellipse or circle will result, not shown, but vertical with respect to the axis of coördinates.

6. Using the wattless component of the fundamental F_u, Fig. 10, and all the harmonics in phase with the flux, curve H, Fig. 10, and plotting a curve with the flux, the line b, Figs. 9 and 12 results. This line should enclose no area since only wattless components of the current wave are used. It is analogous to line a, but is bent or distorted, due to the presence of harmonics. It represents also the average current required for rising and falling magnetization.

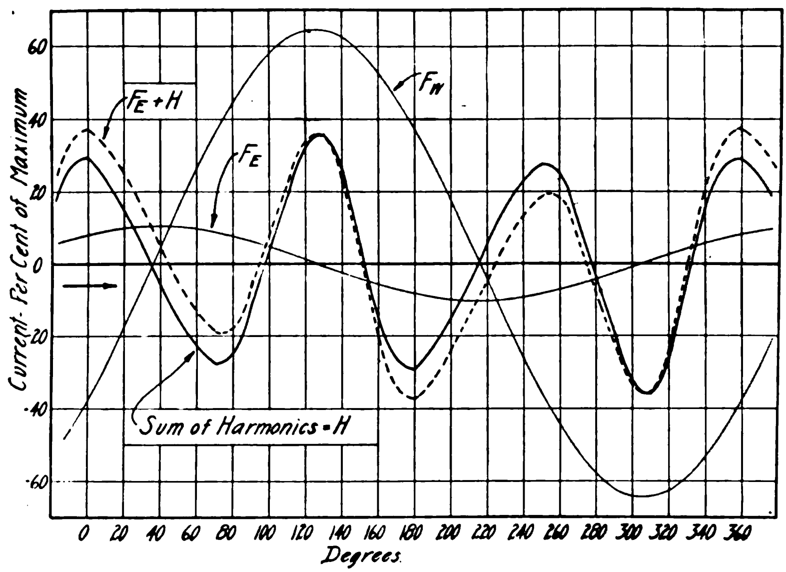


FIG. 13.—Curves plotted from oscillogram No. 24 sheet No. 5 and oscillogram No. 26 sheet No. 5

7. Considering Figs. 5 and 7, attention is called to the fact that the maximum of the third and of the fifth harmonic are not in phase with the maximum of the flux or of the complex wave. If these harmonics are resolved into component parts in phase with the flux and in phase with the voltage, and these components added to similar ones of the fundamental, curves C_w and C_e will result. These curves may also be obtained from curves given in Figs. 5 and 9, as follows:

C_e may be obtained by using as ordinates the abscissa between line b and the hysteresis loop; curve C_w by using as ordinates the abscissa between the vertical axis and the line b.

It is interesting to note that the area enclosed between the curve F_e, Fig. 11, and the horizontal axis, is equal to the area enclosed between the horizontal axis and the curve C_e, Fig. 11. Since this area, in a certain sense, represents the energy supplied the core, we can again conclude that the harmonics do not affect the loss in the core.

The general conclusion to be drawn from these tests and the interpretation of the various curves plotted is that in transformers the distortion of the current wave shape is neither a cause nor an effect of the energy loss in the core, but results only from the varying permeability of the steel. The amount of the distortion varies with the density, since the greater the density the

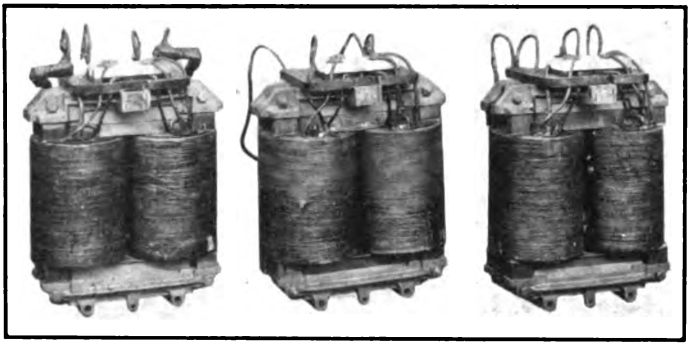


Fig. 14.—Three, single-phase, core-type, 25-cycle, 25-kw. 2300-volt primary, 460 volt secondary transformers used in observing third harmonics

more prominent are the higher harmonics, such as the third, fifth, seventh, ninth, etc.

Investigation of Interconnected Transformers

As an extension to the investigation of a single-phase transformer, observations of harmonics in current and potential wave shapes of interconnected transformers were made. With three transformers, the Y-connection is the most common, and without doubt, the most important connection. For these observations, three single-phase, core-type, 25-cycle, 25-kw., 2300-volt primary, 460-volt secondary transformers were selected, and oscillograms taken of current and potential at different densities in the core. The small capacity was selected

so that the potential wave shape of the relatively small generator available would not be distorted by the current required for the test; the low voltage to avoid the use of both current and potential transformers in measuring current, voltage, and watts.

As preliminary and for further reference, oscillograms of current and potential at different densities were taken single-phase and are shown on Sheets 27 and 27 A. The only special reference to be made to these current curves is the pronounced flattening at the zero point for the higher densities. Root-mean-square values are give in Table 2.

TABLE 2

25 cycle, 25-kw., 2300-volt primary, 46-volt secondary transformers, connected single-phase

B-Kilolines	Volts	Amperes	Watts
45.0	230	0.75	70
90.0	460	6.05	280
112.5	575	27.2	540

The three transformers were connected as shown in Fig. 15 with the 460-volt winding Y-connected, and the 2,300-volt winding connected with the delta open. Current was supplied by a three-phase generator through three single-phase transformers delta-Y connected, as shown. By means of the switch at $E F$, the neutrals between the step-down transformers and the transformers under test could be connected; with the switch

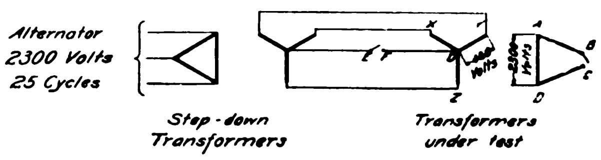


Fig. 15

at $B C$, the delta connection of the transformer under test could be closed.

With the switches at $B C$ and $E F$ open, root-mean-square values of current in the line and voltage across the Y, *i.e.*, across X Z, X Y and $Y Z$; across the leg, *i.e.*, O X, $O Y$ and $O Z$; and across the open delta, and across the open neutral are given in Table 3.

TABLE 3

Three 25-cycle, 25-kw., 2,300-volt primary, 460-volt secondary transformers, connected open delta—isolated neutral

Density in core kilolines per sq. in.	Voltage across				Current in line			Watts
	Lines	Leg	Open delta	Isolated neutral	1	2	3	
22.5	397.5	244.6	1,180	100	0.53	0.54	0.54	167.5
90.0	795	525	3,780	257	3.42	3.27	3.42	675
112.5	995	675	5,040	330.5	15.5	14.3	15.7	1,650*

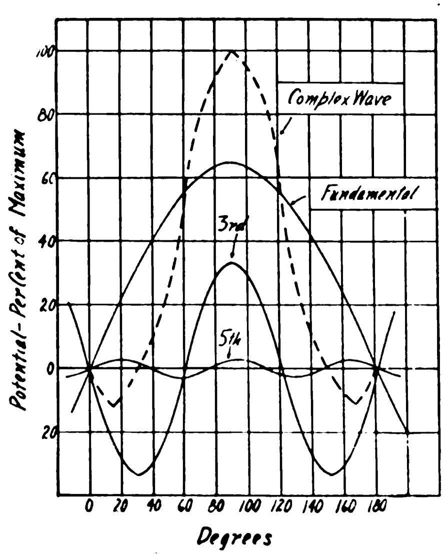
Oscillograms corresponding to a density of 90 kilolines per sq. in. are given in Sheet 13.

Each of the three transformers would require normally for its magnetization a current having a triple frequency component similar to curve No. 159, Sheet 27A. Since the current in a balanced three-phase system cannot contain a triple harmonic (otherwise the sum of the instantaneous values would not equal zero), the current wave shape in Y-connected transformers cannot contain a triple harmonic. Necessarily, the induction in the core must be distorted from the sine shape by an amount corresponding to the value of the triple harmonic component in the current. The resulting induction in the core of each transformer is, therefore, represented by the potential curve No. 77, Sheet 13, and the current flowing in the winding, by curve No. 78, Sheet 13. The analyses of these curves are given in Figs. 16 and 17.

In Fig. 16, attention is called to the relative values of the maximum induction at fundamental, triple, and quintuple frequencies, equal to 64.5 per cent, 33.3 per cent and 2.2 per cent respectively, of the maximum of the complex wave.

In Fig. 17, attention is called to the absence of the triple frequency component of the current and to the pronounced quintuple component. It will be noted also that the sum of the induction at triple and quintuple frequency is equal to 55 per cent of the maximum induction at the fundamental frequency.

Fig. 18 shows the instantaneous values of potential across each of the delta-connected windings of the transformers in their proper phase relation to each other. The triple frequency components in the legs are in phase with each other while the fundamental components are 120 deg. apart and their sum equals zero. The voltage in the delta is, therefore, represented by the curve $C\ B$, Fig. 18, and measured by curve No. 80, Sheet 13. Both curves show a triple frequency potential equal in ampli-



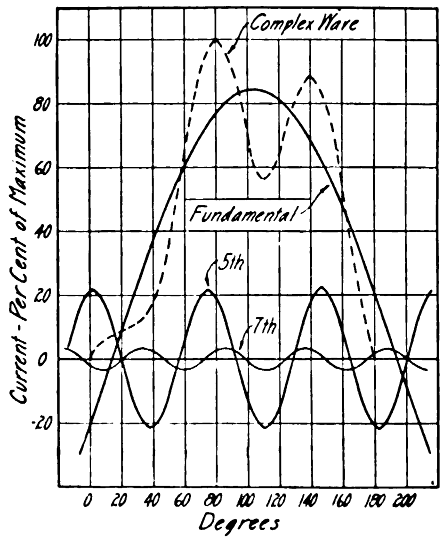
Max. complex wave = 100

$R_1 = 64.5 \qquad \phi_1 = -\ 0°\ 32'$

$R_3 = 33.3 \qquad \phi_2 = 177°\ 56'$

$R_5 = 2.2 \qquad \phi_3 = -15°\ 58'$

FIG. 16.—Analysis of oscillogram No. 77 sheet No. 13



Max. complex wave = 100

$R_1 = 84.2 \qquad \phi_1 = 14°\ 2'$

$R_5 = 21.9 \qquad \phi_5 = 77°\ 21'$

$R_7 = 3.2 \qquad \phi_7 = 214°\ 43'$

FIG. 17.—Analysis of oscillogram No. 78 sheet No. 13

tude to three times that of the triple frequency found in each leg. The root-mean-square voltage read across the open delta is given in Table 3 and confirms the conclusion drawn from the discussion of the curves.

While the sum of the instantaneous current values is equal to zero, the resultant distortion of the potential produces an unbalance in the voltage of the system; *i.e.*, the sum of the instantaneous potential values does not equal zero as is evidenced by the voltage across the open delta and the open neutral.

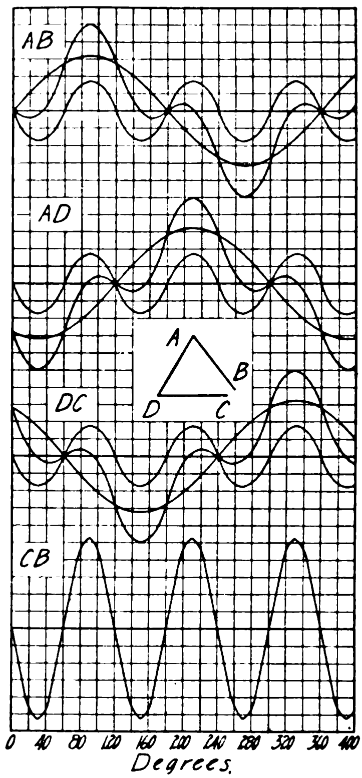


FIG. 18.—Phase relation of voltage across legs and across open delta of delta-connected transformers

In Fig. 19 is shown the instantaneous values of potential across the transformer, *O* X and *O Y*, and across the lines, X *Y* in their proper phase relation. It will be noted that the sum of the instantaneous values of *O* X and *O Y* equals the instantaneous values of X *Y*. The triple frequency components of voltage

being 60 degs. fundamental frequency, or 180 degs. triple frequency apart, neutralize each other, and the resultant potential across the *Y* is a sine shape.

The potential across X *Y*, X *Z*, and *Y Z* is a sine curve, as shown by curve No. 76, Sheet 13, and by Fig. 19. By the connections shown in Fig. 15, a sine potential is insured across each leg of the delta-Y step-down transformers. It has just been noted that the potential across each leg, *O* X, *O Y*, and *O Z*

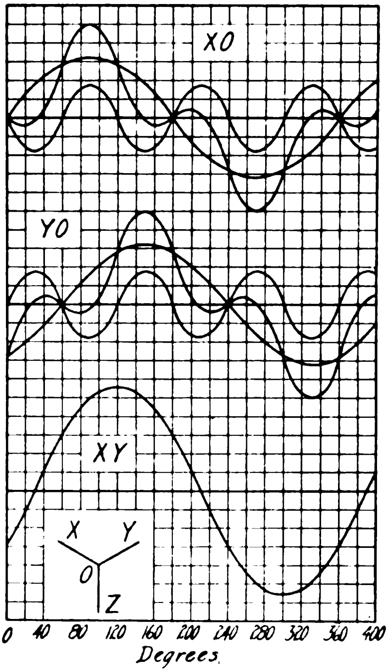


FIG. 19.—Phase relation of voltage across line and across legs of Y-connected transformers

is not a sine potential (see Sheet 15), so that the system is unbalanced with respect to the potential across the neutral *E F* by an amount equal to the triple frequency distortion found in each leg. Curve No. 79, Sheet 13, gives the observed shape.

Root-mean-square values given in Table 3 confirm the above conclusions. With 795 volts applied across the *Y*, (*i.e.*, X *Y*) the voltage across each leg is not $\frac{795}{\sqrt{3}}$, (*i.e.*, 460 volts) but 525

volts. Since effective voltages of different frequencies are added in quadrature, the value of the higher harmonic component is $\sqrt{525^2 - 460^2} = 253$ volts, which agrees quite closely with 257 volts actually read across the open neutral. It should be noted also that 253 volts is 55 per cent of 460, agreeing perfectly with the observation in the discussion of Fig. 16.

Since the distortion applied to the primary winding of the transformer must be reproduced on the secondary winding, the triple frequency potential of 253 volts multiplied by the ratio of transformation should appear on each leg of the delta-connected side of the transformers. The ratio of transformation being 5:1, $5 \times 253 = 1265$ volts. This multiplied by 3—since the triple frequency voltage in the three legs is in phase—gives 3795 volts as against 3780 volts actually observed.

It may be noted that with 795 volts applied across the lines, 2620 volts were read across each leg of the delta, indicating a change or error in the ratio of transformation. This fictitious ratio will not be observed if voltages are read across the primary and secondary windings of each transformer. With 525 volts applied to the low tension winding, 2,620 volts is observed on the high tension winding, indicating the correct ratio. As the discrepancy between the actual ratio and this apparent ratio is due entirely to the triple frequency voltage it disappears as soon as the delta is closed.

The discussion of transformers connected as above applies equally well to any connection in which neither winding of the transformer forms a closed delta, or in which the neutrals are isolated. In several instances, the writer has observed a triple frequency voltage equal to 50 per cent of the fundamental appearing on the secondary side of step-down transformers for synchronous converters, so that when the converters were disconnected, the ratio of the transformers was apparently decreased 20 per cent. This decrease in ratio, of course, immediately disappeared as soon as the synchronous converters were put into operation.

The important detail to be noted in the observations made of this Y-delta connection is the increase in the potential strains distributed throughout the winding of the transformer resulting from the distorted potential wave shape. Excepting in small lighting transformers, where the insulation factor of safety is 5 or 10, this increase in the potential strains greatly reduces the reliability of operation of a transformer. In such transformers in

which the normal fundamental voltage is 70,000 or 80,000 volts and which have an insulation factor of safety of about two, as indicated by the test voltage of 140,000 to 160,000 volts applied, the application of a triple frequency voltage of 40 per cent or 50 per cent of the fundamental may reduce the insulation factor of safety to 1.3 or 1.4—certainly not large enough to insure reliable operation. It should be noted also, from Table 3 and Fig. 16, that while the root-mean-square value of the potential is increased about 25 per cent, the maximum value of the complex wave is very much more increased and since the maximum is

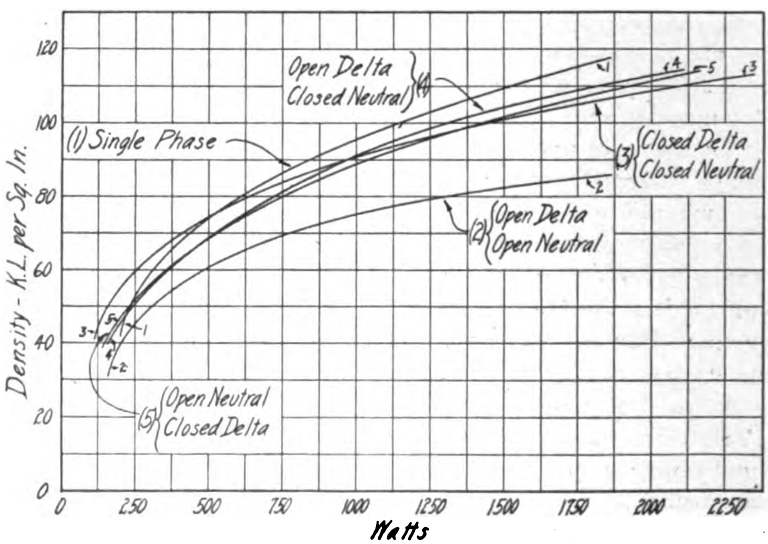


FIG. 20.—Curve of core losses: three single-phase, 25-cycle 25-kw., 2300-volt primary, 460-volt secondary transformers

the puncturing voltage, the actual increase in the voltage strain is not truly indicated by the root-mean-square values as given in Table 3.

The distinction between these strains and those resulting from high frequency surges should be clearly noted. The strains resulting from this potential distortion are equally distributed over all parts of the winding, while those resulting from line surges, short circuits or switching may affect only a small portion of the winding. Attention is also called to the difference in the losses in transformers. Referring to Table 1, we note that, under single-phase excitation, the core loss in each transformer

at a density of 90 kilolines is 280 watts, or 840 for the three transformers, while with the same effective voltage on the transformers connected three-phase, the total core loss is but 675 watts. This difference or reduction in loss is explained by the difference in the maxima of the density in the core under the different connections. Fig. 20 brings out more clearly this difference in core loss under the different connections.

The next step in the discussion is to observe the results obtained from the elimination of the potential distortion cited above by closing the delta. Oscillograms of current and potential are given on Sheet 10. The root-mean-square values are given in Table 4.

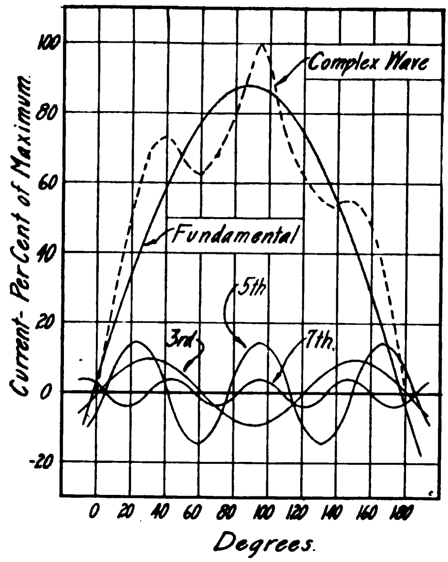
TABLE 4

25-cycle, 25-kw., 2300-volt primary, 460-volt secondary transformers, connected neutral isolated—delta closed.

B-Kilolines	Voltage across			Current in line				Watts
	Lines	Leg	Isolated neutral	1	2	3	Closed delta	
22.5	397.5	234.6	0	0.59	0.58	0.60	0	188
90.0	795	462.5	0	6.30	5.4	5.73	0.63	1,030
112.5	995	575	0	27.7	24.0	27.0	3.2	2,060

It will be noted that the potential wave across the transformers, as well as across the lines X Y, has a sine shape and that the voltage across the open neutral has dropped to zero. This is to be expected from our previous discussion, as the triple frequency harmonic of the current has now been supplied. The value of this current necessary to demagnetize the core is indicated by the 0.63 ampere read in the closed delta. Analysis of oscillogram 65, Sheet 10, is given in Fig. 21, and of oscillogram 66, Sheet 10, is given in Fig. 22. It will be noted that upon closing the switch at C D with 3780 volts observed across the open delta, only a very small current flows. This is consistent as the current is in no sense a load current, but merely the triple frequency exciting current component necessary to demagnetize the core to eliminate the potential distortion.

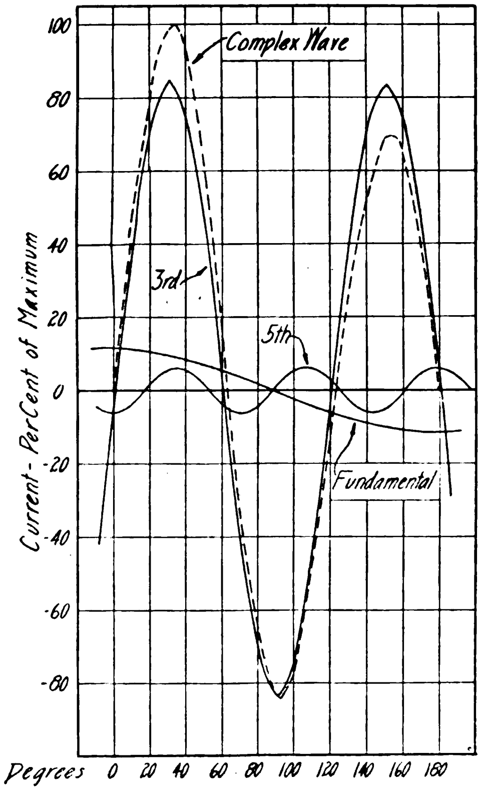
If, instead of supplying the triple frequency current component by closing the delta, it is supplied by connecting the neutrals at E F, the same general results follow, as is shown by the oscillograms on Sheet 12. It will be noted that practically



Max. complex wave = 100

$R_1 = 88.1$	$\phi_1 = 2° 13'$
$R_3 = 9.4$	$\phi_3 = -3° 32'$
$R_5 = 14.4$	$\phi_5 = -24° 13'$
$R_7 = 3.8$	$\phi_7 = 148° 12'$

FIG. 21.—Analysis of oscillogram No. 65 sheet No. 10

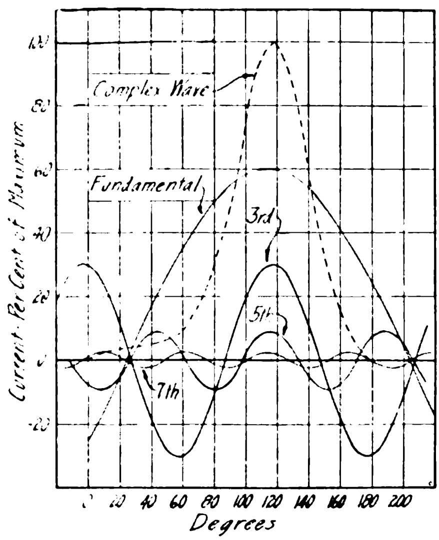


Max. complex wave = 100

$R_1 = 11.2$	$\phi_1 = 88° 28'$
$R_3 = 83.8$	$\phi_3 = -3° 24'$
$R_5 = 6.0$	$\phi_5 = -87° 9'$

FIG. 22.—Analysis of oscillogram No. 66 sheet No. 10

sine potential is applied to each of the transformers, as shown by oscillogram 72, and that the current wave in the transformers has been restored to practically the identical shape required when excited single-phase. A comparison of curve No. 73, sheet 12, and its analysis given in Fig. 23, should be made with curve No. 159, Sheet 27. It will be noted also that the ratio of triple frequency current in the closed neutral to the triple frequency in the closed delta checks with the ratio of triple frequency voltage



Max. complex wave = 100

R_1 = 60.0 $\phi_1 = -23° \ 39'$

R_3 = 30.2 $\phi_3 = 98° \ 15'$

R_5 = 9.0 $\phi_5 = 228° \ 4'$

R_7 = 2.5 $\phi_7 = 20° \ 43'$

FIG. 23.—Analysis of oscillogram No. 73 sheet No. 12

across the open neutral to the voltage across the open delta. Root-mean-square values are given in Table 5.

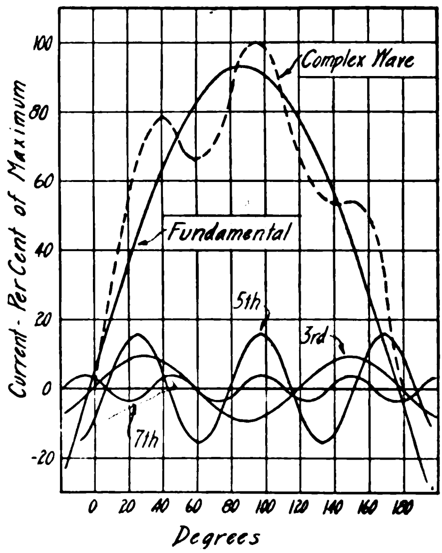
TABLE 5

Three single-phase, core type, 25-cycle, 25-kw., 2300-volt primary, 460-volt secondary transformers, connected delta open neutral connected

	Voltage across			Current in line				
B Kilolines	Lines	Leg	Open delta	1	2	3	Connected neutral	Watts
22.5	397.5	232.9	0	0.60	0.64	0.59	0.455	185
90.0	795	462.5	24.5	6.51	4.83	6.48	9.45	970
112.5	995	575	135	33	26	31.7	46.5	1,975

The final investigation is to note the condition existing with both the neutral and the delta closed. Oscillograms are given on Sheet 11; analyses of curves No. 69 and No. 70 are given in Figs. 24 and 25. Root-mean-square values are given in Table 6.

In order to bring out more clearly the difference in core loss in the transformers under different excitations and different connections, the observations have been plotted in curves shown in Fig. 20.



Max. complex wave = 100

R_1 = 93.2 ϕ_1 = 2° 50′
R_3 = 9.4 ϕ_3 = 1° 49′
R_5 = 14.9 ϕ_5 = −33° 9′
R_7 = 3.8 ϕ_7 = 130° 17′

FIG. 24.—Analysis of oscillogram No. 69 sheet No. 11

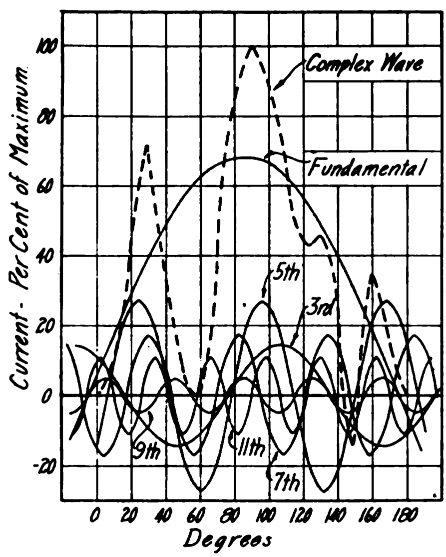
TABLE 6

Three single-phase, core type, 25-cycle, 25-kw., 2300-volt primary, 460-volt secondary, transformers connected delta closed—neutral connected

B-Kilolines	Voltage across		Current in line					Watts
	Lines	Leg	1	2	3	Closed delta	Connected neutral	
22.5	397.5	234.2	0.3	0.28	0.3	0	0	127.5
90.0	795	462.5	4.08	3.45	4.11	0.62	0.76	975
112.5	995	575	27	24.5	27.5	3.2	1.13	2,290

OBSERVATIONS ON A THREE-PHASE CORE TYPE TRANSFORMER

The next step in the investigation was to observe the wave shapes of current and potential on a three-phase core type transformer and to note the influence of the difference in the magnetic circuit of such a transformer as compared with the magnetic circuit of three single-phase transformers. Fig. 26 shows the three-phase core type transformer used in this investigation.



Max. complex wave = 100

R_1 = 68.1	ϕ_1 = 4° 55′
R_3 = 14.2	ϕ_3 = 132° 32′
R_5 = 27.3	ϕ_5 = −30° 48′
R_7 = 17.1	ϕ_7 = 246° 35′
R_9 = 4.9	ϕ_9 = 46° 25′
R_{11} = 10.9	ϕ_{11} = 70° 44′

FIG. 25.—Analysis of oscillogram No. 70 sheet No. 11

As before, a transformer of low voltage and small capacity was selected so that the potential wave shapes applied by the generator would not be distorted by the current required for the test. It should be noted that the magnetization of each of the three legs of the three-phase core is not the result of the current flowing in the coil surrounding it, but is imposed by the resultant effect of the currents around all the legs. The lack of symmetry

between the magnetic circuit of the middle leg and either outside leg also affects the results. The reluctance of the air circuit for each leg being many times the reluctance of the iron circuits, considerably more triple frequency current is required to eliminate the potential distortion, so that the marked distortion of current and potential noted in the single-phase transformers under similar connections is, therefore, absent.

Sheets 6, 7, 8 and 9 give oscillograms of current and potential as before. Tables 7, 8, 9 and 10 give the root-mean-square values.

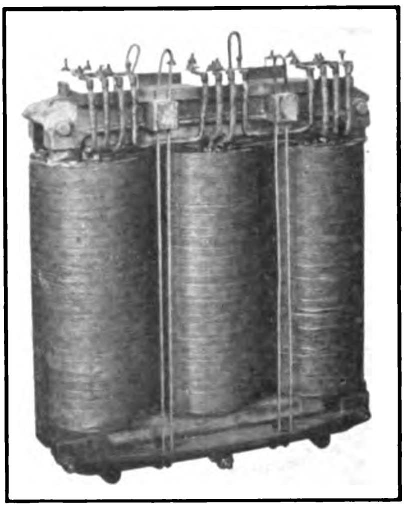


FIG. 26.—Three-phase, core-type, 25-cycle, 40-kw., 2300-volt primary, 460-volt secondary transformer used to investigate third harmonics

TABLE 7

Three-phase, core type, 25-cycle, 40-kw., 2300-volt primary, 460-volt secondary transformers, connected neutral isolated—delta open

B-Kilolines	Voltage across				Current in line			Watts
	Lines	Leg	Open delta	Isolated neutral	1	2	3	
42.6	1150	662	2.5	2.3	0.252	0.234	0.186	210
85.2	2300	1324	50	45	1.34	1.22	1.92	860
106.4	2875	1650	150	135	3.32	2.94	2.64	1960

TABLE 8

Three-phase, core type, 25-cycle, 40-kw., 2300-volt primary, 460-volt secondary transformers, connected isolated neutral—closed delta

B-Kilolines	Voltage across			Current in line				Watts
	Lines	Leg	Isolated neutral	1	2	3	Closed delta	
42.6	1150	662	0	0.234	0.252	0.210	0.076	211.5
85.2	2300	1324	0	1.17	1.32	0.92	0.84	880
106.4	2875	1650	0	3	3.36	2.76	2.93	2040

TABLE 9

Three-phase core type, 25-cycle, 40 kw., 2300-volt primary, 460-volt secondary transformers, connected neutral connected—delta open

B-Kilolines	Voltage across			Current in line				Watts
	Lines	Leg	Open delta	1	2	3	Connected neutral	
42.6	1150	659	0	0.204	0.195	0.171	0.137	213
85.2	2300	1324	0	1.42	1.22	0.92	0.86	880
106.4	2875	1652.5	4	3.16	2.96	2.76	3.25	2040

TABLE 10

Three-phase, core type, 25-cycle, 40-kw., 2300-volt primary, 460-volt secondary transformers, connected delta closed—neutral connected

B-Kilolines	Voltage across		Current in line					Watts
	Lines	Leg	1	2	3	Closed delta	Connected neutral	
42.6	1150	662	1.08	0.096	0.09	0.225	0.223	216
85.2	2300	1324	1.32	1.27	0.82	0.82	0.404	960
106.4	2875	1652.5	3.16	3.26	2.56	3.0	0.7	2120

It should be noted that the potential wave shape across the different legs is not identical, and that the current wave shape in the three legs is also not identical. These differences are explained by the lack of symmetry of the magnetic structure of the different legs and also by the slight difference in the windings of the legs. It will be noted that the same general results follow on the three-phase transformer as were observed in the discussion of the three single-phase transformers.

In Fig. 27, the observed core losses and exciting currents under the different connections are plotted.

The next step in the investigation was the consideration of a three-phase core type transformer with legs symmetrically arranged, as shown in Fig. 28. Oscillograms are given on Sheets 18, 19, 20 and 21, and root-mean-square values at density of 66 kilolines in the core are given in Table 11.

Attention is called to the almost equal values of exciting current for the different windings which was not observed in the unsymmetrical three-phase core type. It will be noted also that as the results of the symmetrical magnetic structure and the

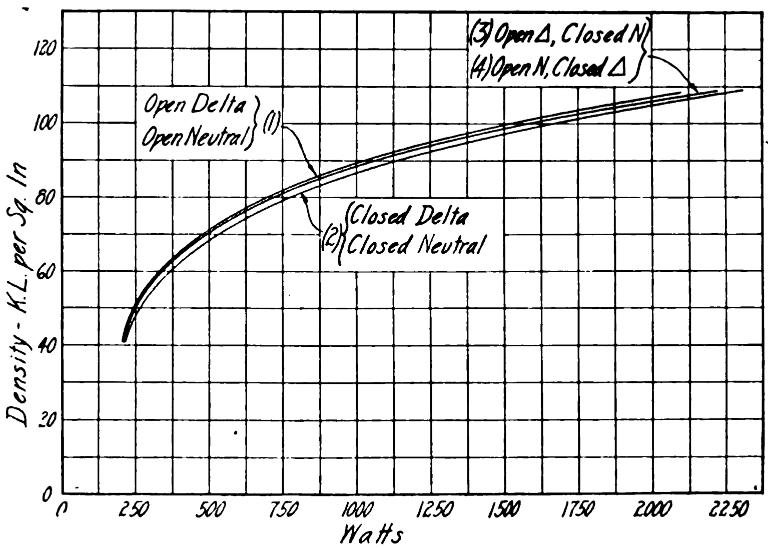


FIG. 27.—Curve of core loss of three-phase, 25-cycle, 40-kw. 2300-volt Y-primary, 460 volt delta secondary

inter-relation of the magnetizing effects, the potential wave shape across the different legs under all connections is practically the same. No doubt, at higher densities, some unbalanced effect would be noted, but at the densities at which tests were taken, none were observed.

For a final series of observations, a three-phase shell type, 60-cycle, 330-kw., 13,200-volt primary, 430-volt secondary transformer was selected, and oscillograms of current and potential observed as given in Sheets 14, 15, 16 and 17. Root-mean-square values at 43 kilolines and 86 kilolines are given in Tables 12 and 13.

TABLE 11

Three-phase, core type, 60-cycle, 200-kw., 4600-volt primary, 2300-volt secondary transformers.

	B-Kilolines	Voltage across				Current in line			Watts
		Lines	Leg	Neutral	Delta	1	2	3	
(1)	66	3980	2275	0	0	1.82	1.70	1.80	3420
(2)	66	3980	2275	0	0	1.97	1.88	1.97	3820
(3)	66	3980	2275	0	0	1.58	1.42	1.6	3610
(4)	66	3980	2275	0	0	2.0	1.92	2.0	3850

(1) Delta closed—neutral connected.
(2) Delta open—neutral isolated.
(3) Delta closed—neutral isolated.
(4) Delta open—neutral connected.

TABLE 12

Three-phase, shell type, 60-cycle, 330-kw., 13,200-volt primary, 430-volt secondary

	B-Kilo-lines	Voltage across				Current in line				Watts
		Lines	Leg	Delta	Neutral	1	2	3	Neutral	
(1)	43	372.5	215	4500	50.1	6.0	6.2	4.76	—	2225
(2)	43	372.5	215	—	—	5.88	6.00	4.86	0	2250
(3)	43	372.5	215	5	—	5.88	6.31	5.37	2.33	2275
(4)	43	372.5	215	—	0	6.0	6.2	4.76	—	2225

(1) Delta closed—neutral connected.
(2) Delta open—neutral isolated.
(3) Delta closed—neutral isolated.
(4) Delta open—neutral connected.

TABLE 13

Three-phase, shell type, 60-cycle, 330-kw., 13,200-volt primary, 430-volt secondary

	B-Kilolines	Voltage across				Current in line				Watts
		Lines	Leg	Delta	Neutral	1	2	3	Neutral	
(1)	86	745	460	9580	102.2	53.7	53.7	36.6	—	9,000
(2)	86	745	430	—	—	60	57.8	45.6	3.5	10,500
(3)	86	745	430	301.5	—	64.2	57.8	60.0	24.9	10,200
(4)	86	745	430	—	0	58.8	57.8	44.6	—	10,000

(1) Delta closed—neutral connected.
(2) Delta open—neutral isolated.
(3) Delta closed—neutral isolated.
(4) Delta open—neutral connected

Fig. 28.—Three-phase, core-type, 25-cycle, 500-kw., 2300-volt primary, 2300-volt secondary transformer used in the investigation of third harmonics

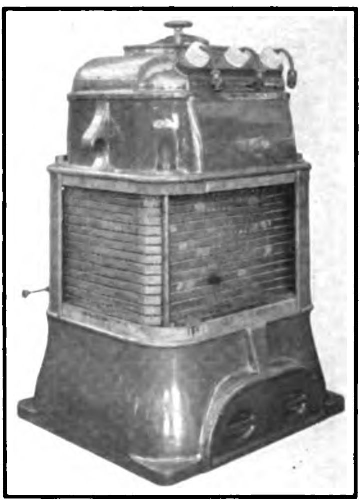


Fig. 29.—Three-phase, shell-type, 60-cycle, 330-kw., 13,200-volt primary, 430-volt secondary transformer used to investigate third harmonics

The general construction of the transformer and diagram of the core structure is shown in Figs. 29 and 30. The unsymmetrical current and potential waves are no doubt explained entirely by the unsymmetrical core structure.

Attention is called to the potential wave shape across the open neutral and open delta, analysis of which is given in Fig. 31. The presence of a fundamental of considerable magnitude is, no doubt, explained by the presence of unbalanced fundamental voltage due to lack of absolute duplication of the windings.

Delta-Connected Transformers

The remaining important connection of interconnected transformers is the delta connection, using either two or three transformers. For this investigation three 25-cycle, 25-kw., 2300-volt primary, 460-volt secondary transformers were

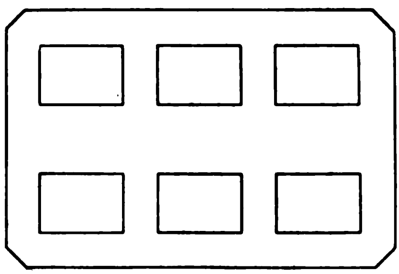
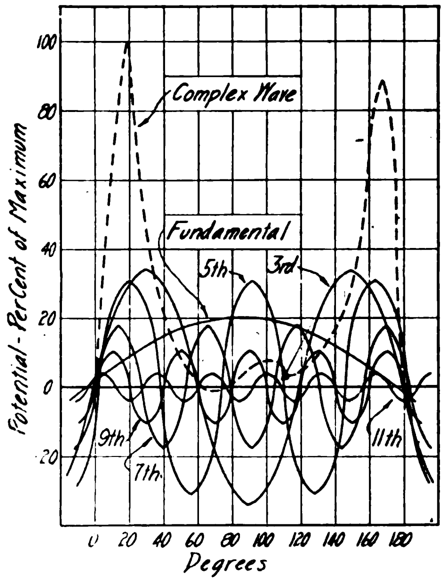


Fig. 30.—Diagram of core structure of three-phase, shell-type, 60-cycle, 330-kw., 13,200-volt primary, 430-volt secondary transformer used to investigate third harmonic

selected and connected as shown in Fig. 32. Sheet 22 gives the oscillograms of current and potential, using the three transformers with delta primary and delta secondary. It will be noted that the currents in the line are almost identical in shape. Reference is made to curve No. 78, Sheet 13, and its analysis given in Fig. 17, which shows no third harmonic, but a decided fifth and seventh.

Sheet 23 gives the oscillograms of current and potential with three transformers delta connected on the primary and two transformers on the secondary, a condition which may arise when one of three delta connected transformers becomes open. It will be noted that there is no appreciable change in the current wave shape. The potential across the open delta shows the usual characteristic of triple frequency voltage and a slight funda-

mental. The current in the primary delta has the characteristic curve of the current in a transformer connected single-phase *i.e.*, has a fundamental and a decided third harmonic. This



Max. complex wave = 100

R_1	= 20.1	ϕ_1	= 4° 49′
R_3	= 33.9	ϕ_3	= 1° 39′
R_5	= 30.8	ϕ_5	= -7° 35′
R_7	= 17.8	ϕ_7	= -4° 16′
R_9	= 10 4	ϕ_9	= -0° 13′
R_{11}	= 4.1	ϕ_{11}	= 41° 44′

FIG. 31.—Analysis of oscillogram No. 104 sheet No.

naturally follows because the transformer with secondary open is excited by the delta connected primary and calls for a current characteristic corresponding to the sine potential applied.

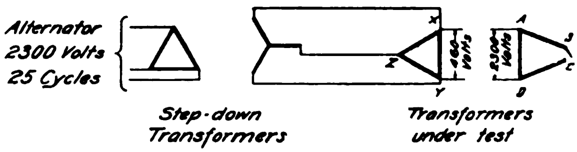


FIG. 32

The next step in the investigation was to open the primary delta as shown in Fig. 33. Sheet 24 gives the oscillograms. It will be noted that the wave shapes across

the lines and across each transformer are identical. The current in the two outside legs shows the usual characteristic of the fundamental and a marked third harmonic. The current in the middle leg, however, shows the presence of a fifth and a seventh harmonic and no third; while the current in legs X and Y conforms to that required when a sine potential is applied across the two transformers connected in series.

Observations on Transformers in Actual Service

To study the conditions found on transformers in actual service, an investigation was made of three transformers connected to the distributing mains of the Rochester Railway & Light Co., Rochester, N. Y. These transformers were rated 60-cycle, 150-kw., 2,400/4,150 Y-volt primary, 480-volt secondary and are similar in their general characteristics to the 25-cycle, 25-kw., 2,300-volt primary, 460-volt secondary transformers previously

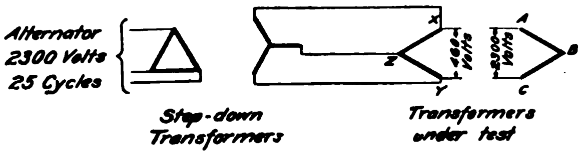


Fig. 33

discussed. The connections to these transformers and the general arrangement of feeders, generators, etc., forming the distributing system are shown in Fig. 34. Transformers are located in substation No. 34, and it will be noted that power is supplied to this substation from alternators in generating stations Nos. 3, 5 and 15, connected in parallel. The following list gives the generators and their prime movers in the different generating stations.

GENERATING STATION NO. 3

Generators				Prime movers
No. of	Poles	Capacity kilowatts	Speed rev. per min.	
3*	80	1360	90	Reciprocating engine.
1	10	3000	720	Steam turbine.
1	24	2100	300	25-cycle induction motor.
2*	16	350	450	Water wheel.

* Originally two-phase, now three-phase T-connected.

GENERATING STATION NO. 5

Generators				Prime movers
No. of	Poles	Capacity kilowatts	Speed rev. per min.	
3	22	1200	327	Water wheels.
1*	16	350	450	Water wheels.
1	24	2100	300	25-cycle induction motor.

GENERATING STATION NO. 15

Generators				Prime movers
No. of	Poles	Capacity kilowatts	Speed rev. per min.	
2	36	500	200	Water wheel.

Oscillograms of the potential wave shape at no load across the terminals, and from terminal to neutral, of these generators are given on Sheet 29. A study of these curves and the list showing the different types of prime movers of the generators would lead one to conclude that results differing from those observed with a single generator having a sine potential should be expected.

Table 14 gives root-mean-square values of potential, current, and watts, taken as before.

TABLE 14.

Single phase, core type, 60 cycle, 150-kw, 2400 4150 Y-volt primary, 480 volt secondary

	Voltage across				Current in line					Watts
	Lines	Leg	Delta	Neutral	A	B	C	Delta	Neutral	
(1)	4250	2705	720	1041	1.1	1.11	1.08	—	—	941
(2)	4342	2540	—	—	38.8	40.6	39.1	180	122	3467
(3)	4233	2453	73	—	1.35	2.0	1.6	—	1.45	1012
(4)	4293	2422	—	125	1.26	1.28	1.06	2.35	—	1025

(1) Open delta—isolated neutral.
(2) Closed delta connected neutral.
(3) Open delta—connected neutral.
(4) Closed delta—isolated neutral.

It should be stated, that these figures could not be as accurately taken as those given in previous tables because of the fluctuations or variations consequent to the varying load of the system.

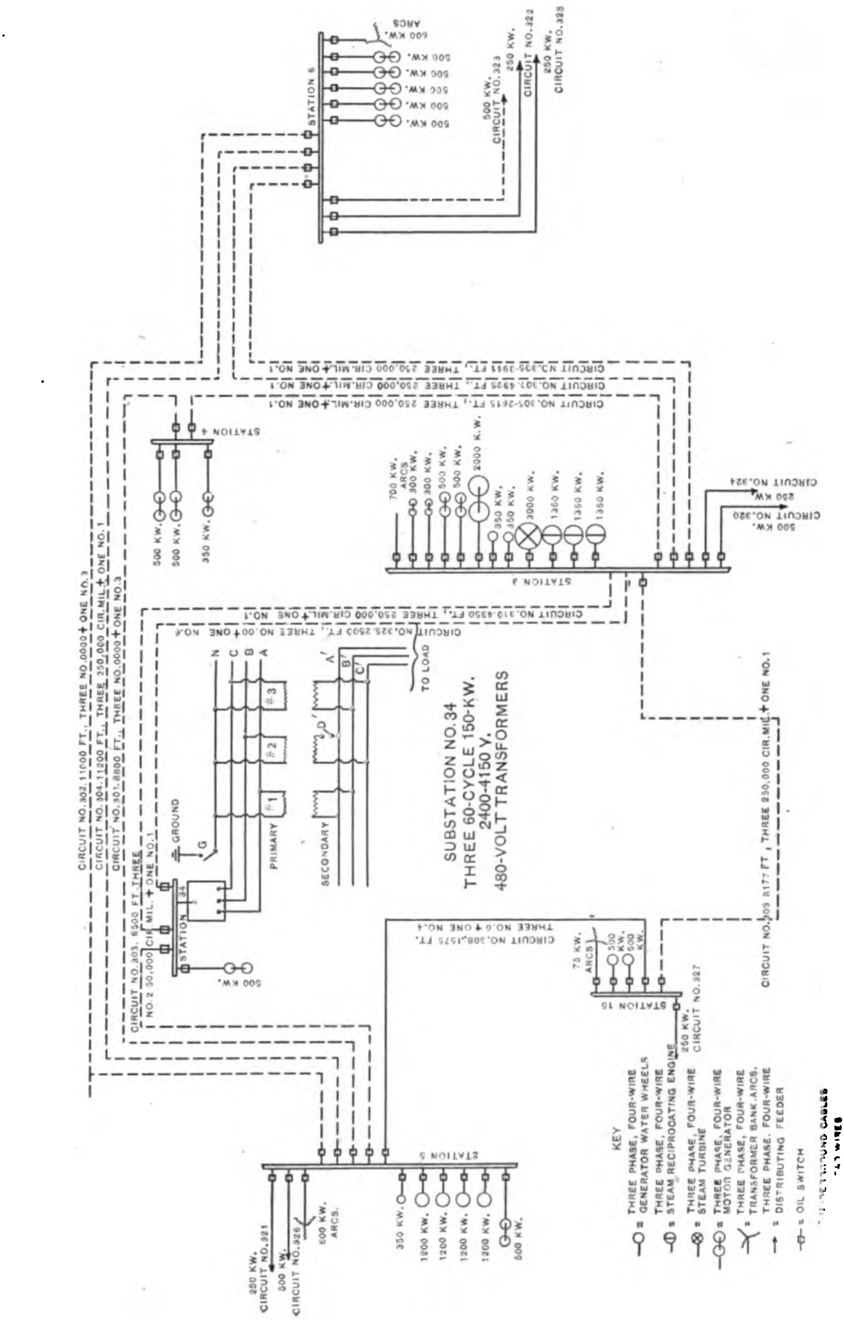


FIG. 34.—Electrical apparatus, the lines and distributing feeders on 4150-volt three-phase system Rochester Railway and Light Company, Rochester, N. Y.

Sheet 4 shows the usual oscillograms of current and potential with the neutral isolated and with the secondary delta open. Curve No. 16, the potential across the lines or mains, is almost a perfect sine wave. Curve No. 17, the potential across each transformer, shows the usual characteristic wave shape distorted due to the third harmonic. (For comparison, see curve No. 77, Sheet 13, and analysis given in Fig. 16.) Curve No. 18, current in the line, shows the presence of the fifth harmonic. (Compare also curve No. 78, Sheet 13, and analysis, Fig. 17). Curves No. 19 and No. 20 show triple frequency across the isolated neutral and open delta.

Sheet 3 gives oscillograms with the neutral connected and the delta open. As previously observed, it is noted that with the neutral closed, allowing triple frequency current to flow in the neutral (curve No. 14), the potential across each transformer is practically a sine wave shape (curve No. 12). The current in the line is changed and has the expected characteristic containing a third harmonic. (Refer to curve No. 23, Sheet 5, and analysis, Fig. 6). The difference in the amplitude of the triple frequency current in the neutral is due to the presence of some fundamental current. Curve No. 15, potential across the open delta, shows in addition to a voltage of triple frequency, a component of the fundamental and a component of higher frequency, presumably the ninth.

Sheet 1 gives oscillograms with the neutral open and the delta closed. It would be expected that the results as observed on Sheet 3, with the neutral closed and delta open, would be reproduced with the neutral open and the delta closed. This is confirmed by the oscillograms. Curves No. 1 and No. 2 show practically a sine potential across the line and across the transformer. Curve No. 3, current in the line, shows the usual distortion. Curve No. 4, the potential across the open neutral, has the same shape as the potential across the open delta, curve No. 15, Sheet 3. Curve No. 5, current in the closed delta, has the same characteristics as curve No. 14, Sheet 3, current in the closed neutral.

Attention is called to the fact that when a path is provided for the circulation of the triple frequency current by either closing the delta or connecting the neutral, the voltage across the open neutral or across the open delta should be zero. The observed fact that there is considerable voltage of triple frequency across the open neutral and open delta would indicate that there

is some disturbance on the system which cannot be overcome by the triple frequency magnetizing current supplied to the core.

Oscillograms with both neutral and delta closed are given on Sheet 2 and contrary to the previous observations, it will be noted that a marked triple frequency current is present in the line (curve No. 8) and in the neutral (curve No. 9) and in the closed delta (curve No. 10). The explanation for this is given by the fact that the generating system produces an electromotive force between neutral and line having a triple frequency component, as indicated by the oscillograms on Sheet 29. The potential across the line is free from this triple frequency disturbance. When the neutral of the transformers is connected to the neutral of the generating system, this triple frequency disturbance is applied to the primary of each transformer and is reproduced on the secondary, as evidenced by curve No. 15, Sheet 3. By closing the delta, the triple frequency components in each leg of the secondary delta, being in the same phase, produce an energy current dependent on the resistance and reactance of the mains and of the transformers. This current must be supplied by the primary winding and the ratio of currents in the two windings is practically the same as the ratio of transformation. The current in the neutral of the primary winding should be about three times the current in the line. Reference to Table 14 will confirm this.

The difference between the effect of a triple frequency component forced upon the transformers by the generating system and a triple frequency component created by the magnetization characteristics should be clearly distinguished. Referring to Sheet 3 and Table 14, it will be noted that triple frequency voltage forced upon the transformers by the generating system produced a large current with the delta connected or closed, since these components of each transformer are in phase with each other. Small voltage will call for heavy current, which is only limited by the resistance and reactance of the transformer. The triple frequency voltage created by the magnetic characteristics of the core is suppressed by a very small demagnetizing current, as shown in the various oscillograms previously referred to.

In the present instance, this heavy triple frequency current flowing in the neutral and the line compelled the operating company to disconnect the neutral of the transformers from the neutral of the system. This was practically the only solution to

the difficulty without disturbing the whole distributing system. Another solution of the difficulty would have been to use transformers delta-Y connected across each generator, using the neu-

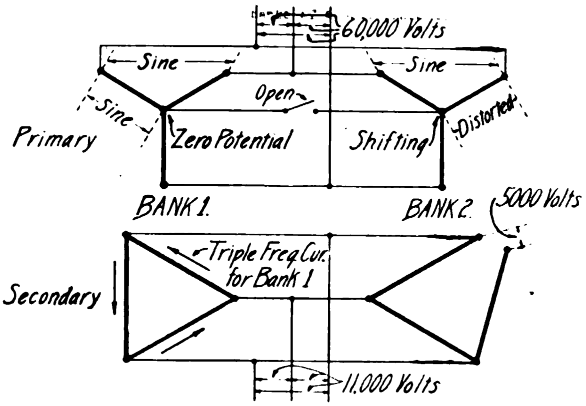


FIG. 35A.—Diagram showing distribution of triple frequency current and voltage in parallel banks of single-phase transformers

tral of the Y connection for the neutral of the general distributing system.

As an important example of the confusing conditions occurring

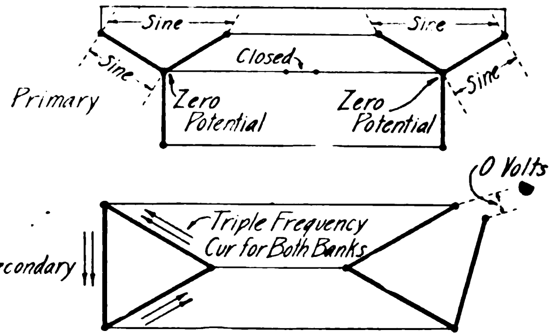


FIG. 35B.—Diagram showing distribution of triple frequency current and voltage in parallel banks of single-phase transformers

in practice resulting from potential wave distortion, the following case may be cited:

Figs. 35*a*, *b*, *c*, *d*, represents two parallel banks of transformers with 60,000-volt Y primary and 11,000-volt delta secondary.

Occasion arose in which it was necessary to disconnect one of the transformers in bank No. 2. In replacing it and attempting to "phase out" the connections, 5,000 volts were measured

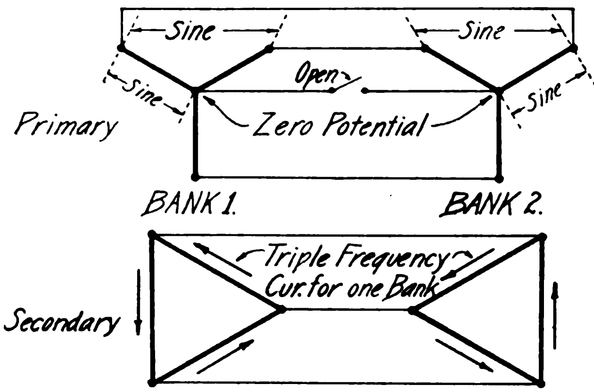


FIG. 35C.—Diagram showing distribution of triple frequency current and voltage in parallel banks of single-phase transformers

across the open delta, indicating a very unbalanced condition. A study of the conditions existing will show that this should have been expected. With the neutrals of the two banks isolated and the delta of bank No. 2 open and that of bank No. 1 closed, a sine

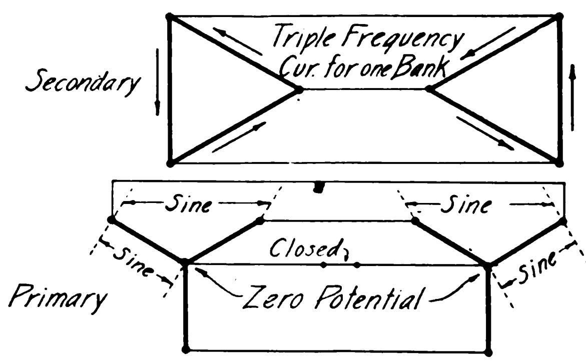
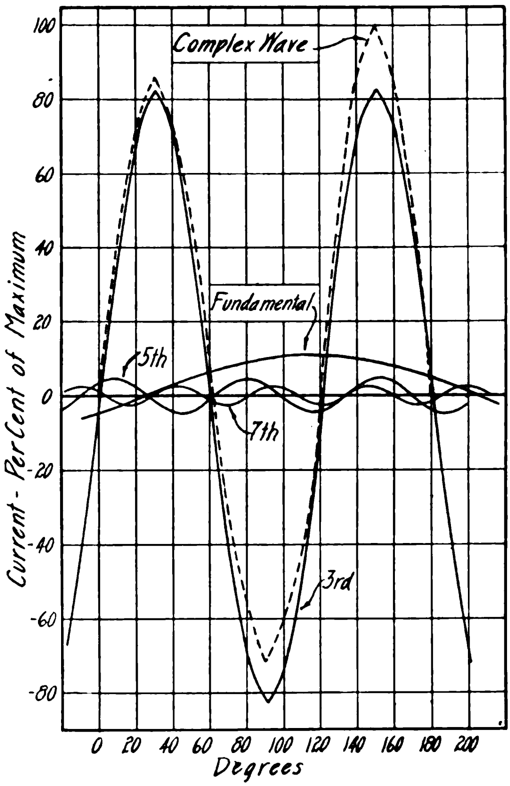


FIG. 35D.—Diagram showing distribution of triple frequency current and voltage in parallel banks of single-phase transformers

potential wave shape is maintained across the transformers of bank No. 1 by the triple frequency current supplied by the closed delta. The neutral of this bank should be at zero potential with respect to the ground.

With the neutral of bank No. 2 open, while the potential across the 60,000-volt line may be a sine shape, no provision is made to insure a sine potential across each transformer, and consequently the two banks are unbalanced across the neutrals by an amount equal to the distorted potential across each leg of



Max. complex wave = 100

R_1 = 10.8 ϕ_1 = −24° 36′

R_3 = 82.9 ϕ_3 = −2° 11′

R_5 = 4.9 ϕ_5 = 48° 19′

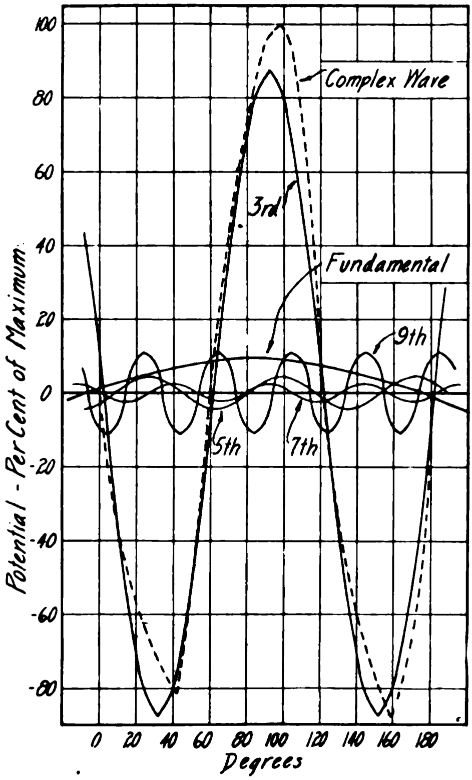
R_7 = 2.6 ϕ_7 = 150° 58′

FIG. 36.—Analysis of oscillogram No. 74 sheet No. 12

bank No. 2; *i.e.*, the neutral shifts and there is an unbalancing of voltage across the open delta of bank No. 2.

By connecting the neutrals, all triple frequency disturbances disappear and sine potential is applied to the transformers of both banks, the necessary triple frequency current being supplied

for both banks by the closed delta of bank No. 1. Upon closing the delta of bank No. 2, the voltage now read across the open delta will be zero, and the secondary windings of both banks will equally contribute the necessary triple frequency currents to



Max. complex wave = 100

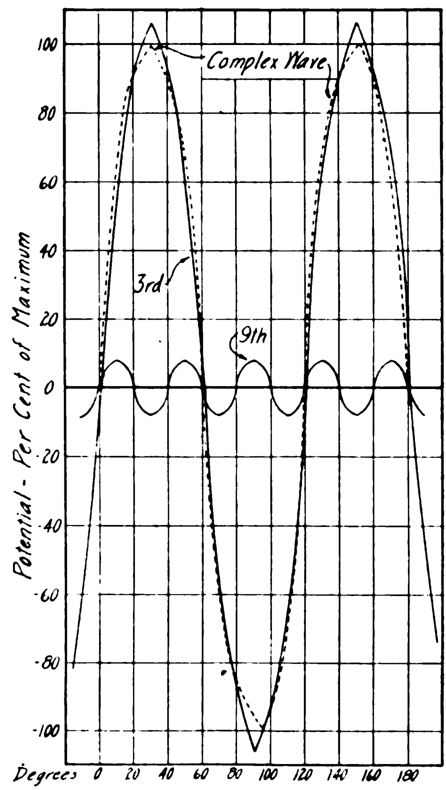
$R_1 = 9.2$	$\phi_1 = 7° \ 1'$
$R_3 = 87.7$	$\phi_3 = 172° \ 32'$
$R_5 = 4.4$	$\phi_5 = -44° \ 3'$
$R_7 = 2.3$	$\phi_7 = 177° \ 43'$
$R_9 = 11.2$	$\phi_9 = 236° \ 8'$

FIG. 37.—Analysis of oscillogram No. 75 sheet No. 12

maintain sine potential across the transformers of both banks. Under such conditions, the connection between the neutrals of the primaries of the two banks may be open or disconnected entirely without any disturbance or change in the potential wave shape applied to the transformers.

It is evident that the investigation and observations of the distribution of current and potential has great practical value.

The broadest general conclusion to be drawn from the observations presented in this paper, so far as they relate to transformers, is that in any distributing system disturbances of current and potential are to be expected unless provision is made to maintain sine potential across the individual transformers.



Max. complex wave = 100

R_3 = 106.0 ϕ_3 = − 2° 26′

R_9 = 8.1 ϕ_9 = 3° 9′

FIG. 38.—Analysis of oscillogram No. 79 sheet No. 13

The writer takes this opportunity to acknowledge assistance in the discussion and analysis of the curves to Mr. W. W. Lewis.

APPENDIX

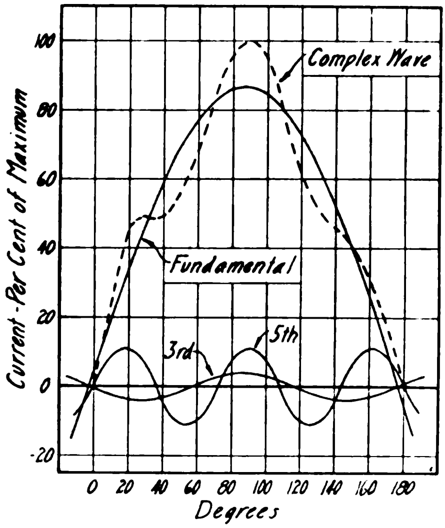
The analysis of the waves in the foregoing article was carried on by the method of Professor S. P. Thompson, as given in Vol. II

of his work on Dynamo Electric Machinery. A brief outline of the method may be of interest.

The following fundamental assumptions are made:

1. Any periodic complex wave, according to the theorem of Fourier, may be considered as built up of a series of harmonic terms, the fundamental one of the series being of the same frequency as the given complex wave. This theorem may be expressed by the following equation:

$$y = R_1 \sin(\theta + \phi_1) + R_3 \sin(3\theta + \phi_3) + R_5 \sin(5\theta + \phi_5) \quad \textbf{(A)}$$
$$+ \ldots\ldots\ldots\ldots \text{etc.}$$



Max. complex wave = 100
R_1 = 86.8 ϕ_1 = 3° 6′
R_3 = 3.6 ϕ_3 = 189° 46′
R_5 = 11.1 ϕ_5 = 1° 14′

FIG. 39.—Analysis of oscillogram No. 83 sheet No. 14

where R_1, R_3, etc., are the amplitudes of the harmonics, and ϕ_1, ϕ_3, etc., are the angles of lag with respect to the zero of the complex wave.

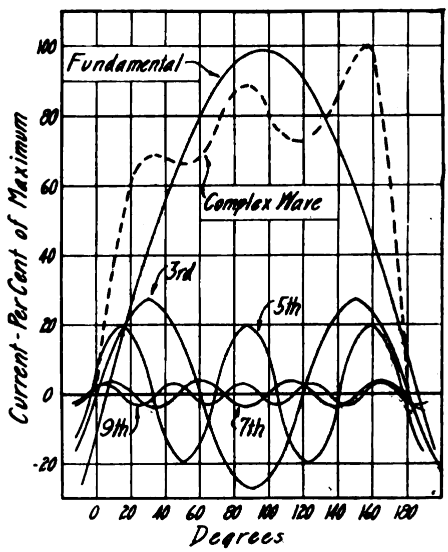
2. As indicated by equation (**A**), only odd harmonics are present, a well-known characteristic of alternator wave.

3. The lagging harmonics in equation (**A**) may be resolved into two components; one a sine curve with zero lag and the other a sine curve with a lag of 90 degs.; in other words, a sine curve in

phase with the complex wave and a cosine curve. Equation (**A**) may then be written

$$y = A_1 \sin \theta + B_1 \cos \theta + A_3 \sin 3\,\theta + B_3 \cos 3\,\theta + A_5 \sin 5\,\theta + B_5 \cos 5\,\theta + \ldots \text{ etc.} \quad (\mathbf{B})$$

4. The mean horizontal axis of the curve is midway between the highest and lowest points of the curve, and the origin or



Max. complex wave = 100

$R_1 = 98.8$ $\phi_1 = -5° \, 43'$

$R_3 = 27.2$ $\phi_3 = -1° \, 13'$

$R_5 = 19.9$ $\phi_5 = 15° \, 32'$

$R_7 = 3.7$ $\phi_7 = 29° \, 51'$

$R_9 = 3.1$ $\phi_9 = 48° \, 22'$

FIG. 40.—Analysis of oscillogram No. 84 sheet No. 14

zero point of the complex wave may be chosen where this curve crosses the horizontal axis.

5. The positive and negative portions of the waves under consideration are identical, so that only a half-wave, *i.e.*, 180 degs. need be considered.

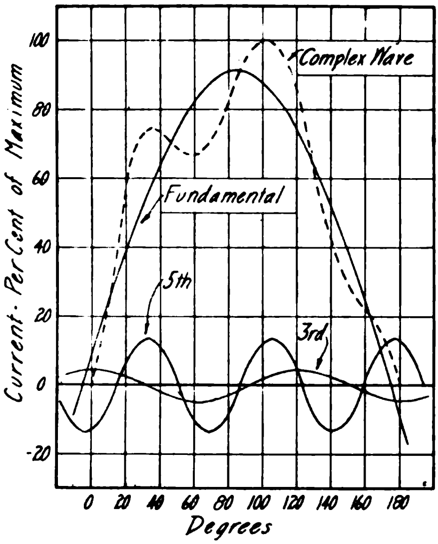
6. If the half-wave is symmetrical to the right and left of 90 degs., only sine terms are present. If not symmetrical in this respect, both sine and cosine terms are present. The latter is the usual case and in general need be the only one considered.

The problem is to find the unknown coefficients A_1, A_3, A_5, etc., and B_1, B_3, B_5, etc. These may then be combined to find R_1, R_3, R_5, etc., by the equation

$$R_1 = \sqrt{A_1^2 + B_1^2} \tag{C}$$

and the angles ϕ_1, ϕ_3, ϕ_5, etc., by the equation

$$\phi_1 = \tan^{-1} \frac{B_1}{A_1} \tag{D}$$



Max. complex wave = 100

R_1 = 91.0	ϕ_1 = 5° 22′
R_3 = 4.5	ϕ_3 = 83° 58′
R_5 = 13.7	ϕ_5 = 73° 20′
R_7 = 2.6	ϕ_7 = 238° 24′

FIG. 41.—Analysis of oscillogram No. 85 sheet No. 14

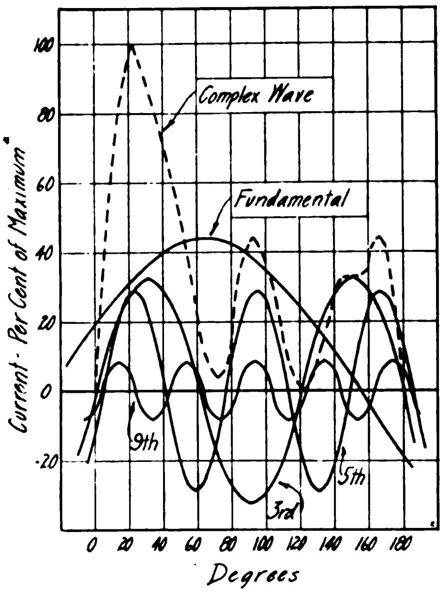
Consider that only the first three harmonics in the series are required, *i.e.*, fundamental, third and fifth. We must then find six unknowns, *viz.*, A_1, A_3, A_5, and B_1, B_3, B_5, and consequently must have six equations. If sine terms only were present, we might choose three convenient points on the wave whose ordinates would then satisfy the following equations:

$$\begin{aligned} y_1 &= A_1 \sin \theta_1 + A_3 \sin 3\,\theta_1 + A_5 \sin 5\,\theta_1 \\ y_2 &= A_1 \sin \theta_2 + A_3 \sin 3\,\theta_2 + A_5 \sin 5\,\theta_2 \\ y_3 &= A_1 \sin \theta_3 + A_3 \sin 3\,\theta_3 + A_5 \sin 5\,\theta_3 \end{aligned} \tag{E}$$

which equations may be solved simultaneously for A_1, A_3 and A_5. Similarly, if cosine terms only were present, three other equations might be formed, *viz.*,

$$\begin{aligned} y_0 &= B_1 \cos \theta_1 + B_3 \cos 3\,\theta_1 + B_5 \cos 5\,\theta_1 \\ y_1 &= B_1 \cos \theta_2 + B_3 \cos 3\,\theta_2 + B_5 \cos 5\,\theta_2 \\ y_2 &= B_1 \cos \theta_3 + B_3 \cos 3\,\theta_3 + B_5 \cos 5\,\theta_3 \end{aligned} \qquad \textbf{(F)}$$

and solved simultaneously for B_1, B_3, B_5. If both sine and cosine terms are present, then each ordinate chosen is made up



Max. complex wave = 100

$R_1 = 43.8$	$\phi_1 = 25° 50'$
$R_3 = 32.4$	$\phi_3 = -2° 40'$
$R_5 = 28.7$	$\phi_5 = -26° 45'$
$R_9 = 8.5$	$\phi_9 = 35° 11'$

FIG. 42.—Analysis of oscillogram No. 91 sheet No. 15

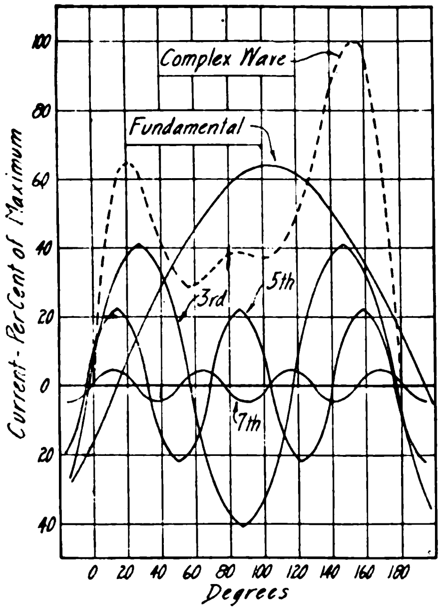
of two portions, the ordinate of the sine component and the ordinate of the cosine component of the wave at that point, and their separation may be accomplished as follows:

It is known that $\sin \theta = \sin (180° - \theta)$ and that $\cos \theta = -\cos (180° - \theta)$. Take an ordinate y_θ (θ less the 90°) and an ordinate $y_{(180°-\theta)}$. If we add these ordinates, any component parts due to $\cos \theta$, $\cos 3\,\theta$, $\cos 5\,\theta$, etc., will cancel while any component parts due to $\sin \theta$, $\sin 3\,\theta$, $\sin 5\,\theta$, etc., will be doubled. If we

subtract $y_{(180°-\theta)}$ from y_θ, the sine components will cancel, leaving the doubled cosine components. That is, expressed algebraically,

$$\left.\begin{aligned} s_1 &= y_\theta + y_{180°-\theta} = 2\,(A_1 \sin\theta_1 + A_3 \sin 3\,\theta_1 + A_5 \sin 5\,\theta_1) \\ d_1 &= y_\theta - y_{180°-\theta} = 2\,(B_1 \cos\theta_1 + B_3 \cos 3\,\theta_1 + B_5 \cos 5\,\theta_1) \end{aligned}\right\} \quad \textbf{(G)}$$

We may thus find a number of ordinates, $\frac{s_1}{2}$, $\frac{s_2}{2}$, $\frac{s_3}{2}$, which may be substituted for y_1, y_2, y_3, in equation (**E**) and a similar set of



Max. complex wave = 100

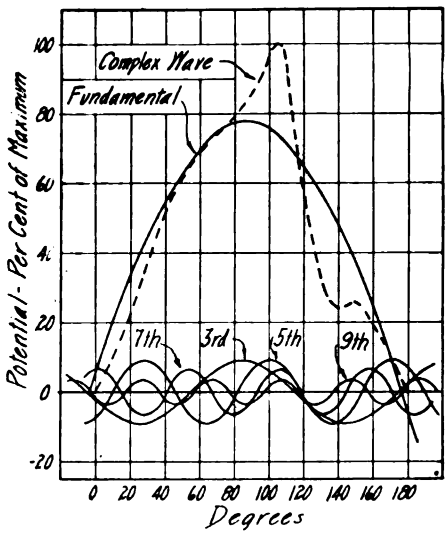
R_1 = 63.9 ϕ_1 = −14° 0′
R_3 = 41.0 ϕ_3 = 8° 28′
R_5 = 22.1 ϕ_5 = 21° 54′
R_7 = 4.8 ϕ_7 = 10° 11′

FIG. 43.—Analysis of oscillogram No. 97 sheet No. 16

ordinates $\frac{d_1}{2}$, $\frac{d_2}{2}$, $\frac{d_3}{2}$, which may be substituted for y_0, y_1, y_2, in equation (**F**), and equations (**E**) and (**F**) solved simultaneously for A_1, A_3, A_5, and B_1, B_3, B_5. The amplitudes R_1, R_3, R_5, and angles ϕ_1, ϕ_3, ϕ_5, may then be found from equations (**C**) and (**D**).

It is apparent that if we consider the complex wave to be made

up of a fundamental, third, and fifth harmonics, and there also happens to be a seventh or other higher harmonic present, the amplitudes that we find on the assumption that the first three harmonics only are present, will each contain a portion of the amplitudes belonging to the seventh and higher harmonics, and the analysis is an approximation to that extent. Therefore, the more harmonics for which we strive, the more accurate will be the analysis, also the more complicated the simultaneous equations



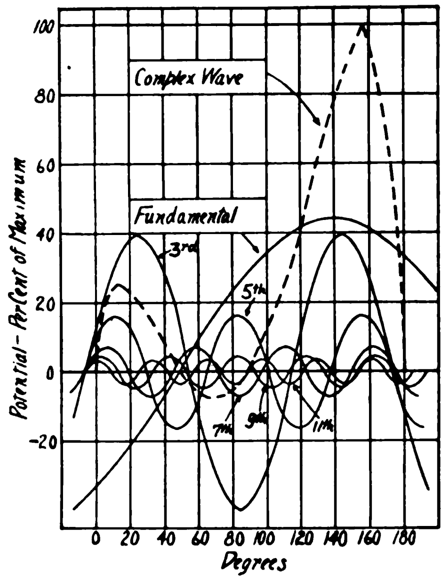
Max. complex wave = 100

$R_1 = 77.9$	$\phi_1 = 3° 57'$
$R_3 = 8.9$	$\phi_3 = 195° 26'$
$R_5 = 9.1$	$\phi_5 = -49° 39'$
$R_7 = 6.9$	$\phi_7 = 78° 55'$
$R_9 = 3.6$	$\phi_9 = 203° 28'$

FIG. 44.—Analysis of oscillogram No. 99 sheet No. 17

to be handled. An analysis for all the harmonics up to and including the eleventh is sufficiently accurate for nearly all cases and requires the handling of six simultaneous equations, which is about as many as it is practicable to deal with. For this purpose, the quarter-wave is divided into six intervals of 15 deg. each and the ordinates measured by means of a dividing engine. These ordinates are combined with the ordinates of the supplementary angles in the second quarter of the wave, giving the sums s_1, s_2, etc., and the differences d_1, d_2, etc., to be substituted

in the proper equations. By means of a schedule prepared by Professor Thompson and slightly modified for our use, the solution of the simultaneous equations is greatly facilitated. The complete analysis of curve No. 78, Sheet 13, shown in detail in Fig. 17, is appended to show the use of this schedule.



Max. complex wave = 100

$R_1 = 44.1$ $\phi_1 = -48° 59'$
$R_3 = 39.8$ $\phi_3 = 16° 42'$
$R_5 = 16.2$ $\phi_5 = 33° 21'$
$R_7 = 7.11$ $\phi_7 = 49° 49'$
$R_9 = 4.76$ $\phi_9 = 61° 29'$
$R_{11} = 3.48$ $\phi_{11} = 74° 36'$

FIG. 45.—Analysis of oscillogram No. 128 sheet No. 22

SCHEDULE FOR THE ANALYSIS OF A PERIODIC CURVE IN WHICH APPEAR ONLY ODD HARMONICS UP TO THE ELEVENTH

(1)	1	2	3	4	5	6.
	$y_1 = 7.6$	$y_2 = 11.2$	$y_3 = 24.0$	$y_4 = 65.0$	$y_5 = 96.1$	$y_6 = 90.0$
	$y_{11} = 37.3$	$y_{10} = 78.8$	$y_9 = 86.4$	$y_8 = 65.0$	$y_7 = 61.8$	
Sum	44.9	90.0	110.4	130.0	157.9	90.0
Dif.	−29.7	−67.6	−62.4	0.0	34.3	

(2)	$s_1 + s_3 - s_5$	$s_2 - s_6$	$d_1 - d_3 - d_5$
	44.9	90.0	29.7
	110.4	−90.0	34.3
	155.3		−64.0
	−157.9		62.4
	$r_1 = -2.6$	$r_2 = 0.0$	$e_1 = -1.6$

(3)

SINE TERMS

Sine	1st and 11th		3rd and 9th		5th and 7th	
0.262	$s_1 = 11.8$				$s_5 = 41.4$	
0.500		$s_2 = 45.0$				$s_2 = 45.0$
0.707	$s_3 = 78.2$		$r_1 = 1.84$		$-s_3 = 78.2$	
0.866		$s_4 = 112.7$				$-s_4 = 112.7$
0.966	$s_5 = 152.3$				$s_1 = 43.4$	
1.000		$s_6 = 90.0$		$r_2 = 0.0$		$s_6 = 90.0$
1st col.	242.3		-1.84		6.6	
2nd col.	247.7		0.0		22.3	
Sum	$6A_1 = 490.0$		$6A_3 = -1.84$		$6A_5 = 28.9$	
Diff.	$6A_{11} = -5.4$		$6A_9 = -1.84$		$6A_7 = -15.7$	
	$A_1 = 81.7$		$A_3 = 0.31$		$A_5 = 4.8$	
	$A_{11} = 0.9$		$A_9 = -0.31$		$A_7 = -2.6$	

COSINE TERMS

0.262		$d_5 = 9.00$				$d_1 = -7.79$
0.500	$d_4 = 0$				$d_4 = 0$	
0.707		$d_3 = -44.1$		$e_1 = -1.13$		$-d_3 = 44.1$
0.866	$d_2 = -58.6$				$-d_2 = 58.6$	
0.966		$d_1 = -28.7$				$d_5 = 33.2$
1.000			$-d_4 = 0$			
1st col.	-58.6		0		58.6	
2nd col.	-63.8		-1.13		69.5	
Sum	$6B_1 = -122.4$		$6B_3 = -1.13$		$6B_5 = 128.1$	
Diff.	$6B_{11} = 5.2$		$6B_9 = 1.13$		$6B_7 = -10.9$	
	$B_1 = -20.4$		$B_3 = -0.19$		$B_5 = 21.4$	
	$B_{11} = 0.9$		$B_9 = 0.19$		$B_7 = -1.8$	

(4) $R_1 = \sqrt{81.7^2 + 20.4^2} = 84.2$ $\quad \tan\phi_1 = \frac{-20.4}{81.7} = -0.25$

$R_3 = \sqrt{0.31^2 + 0.19^2}$ = negligible $\quad \tan\phi_3 = \quad =$

$R_5 = \sqrt{4.8^2 + 21.4^2} = 21.9$ $\quad \tan\phi_5 = \frac{21.4}{4.8} = 4.46$

$R_7 = \sqrt{2.6^2 + 1.8^2} = 3.2$ $\quad \tan\phi_7 = \frac{-1.8}{-2.6} = 0.693$

$R_9 = \sqrt{0.31^2 + 0.19^2}$ = negligible $\quad \tan\phi_9 = \quad =$

$R_{11} = \sqrt{0.9^2 + 0.9^2}$ = negligible $\quad \tan\phi_{11} = \quad =$

$\phi_1 = 14° 2$ $\quad \phi_7 = 214° 43'$

$\phi_3 =$ $\quad \phi_9 =$

$\phi_5 = 77° 21'$ $\quad \phi_{11} =$

NOTE

The following paper is to be read at the 27th annual convention of the American Institute of Electrical Engineers at **Jefferson, N. H., June 27-30, 1910.** This paper is to be presented under the auspices of the High Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, 60 Wall Street, New York,** so that they will be received not later than June 20, 1910.

A paper to be presented at the 27th Annual Convention of the American Institute of Electrical Engineers, Jefferson, N. H., June 27-30, 1910.

(*Subject to final revision for the Transactions.*)

DISRUPTIVE STRENGTH WITH TRANSIENT VOLTAGES

BY JOSEPH L. R. HAYDEN AND CHARLES P. STEINMETZ

I. General

Experience with high voltage transmissions and distributions shows that high frequency oscillations and other disturbances of limited power do not exert as high a disruptive effect, at least on oil and solid insulation, as should be expected from their voltage. Discharges have been observed between the terminals of high-potential oil transformers through the air, which require voltages far beyond those which the transformer insulation could stand, and the absence of a break-down of the transformer could not always be explained by the screening effect of the reactance of the transformer leads.

In his early investigations on high-frequency currents, nearly a generation ago, Professor Elihu Thomson observed that, relative to air, oil has a much greater disruptive strength for high-frequency oscillations than for steadily applied alternating voltages. More recently Professor E. E. F. Creighton has, as the result of his investigations, expressed the opinion that there is an appreciable, though very small, time lag even with air; that is, disruptive discharge does not occur instantly with the application of the voltage, but some time elapses before disruption occurs. This time depends on the nature of the insulating material, and also on the shape of the discharge path. This phenomenon is of industrial importance in the protection of electric circuits against over voltages of short duration, in two ways:

A spark gap of small time-lag may protect the insulation of apparatus against momentary voltages, even if set for a discharge voltage higher than the voltage which the apparatus could stand

when continuously applied, if the time-lag of disruptive strength of the insulation of the apparatus is much greater than that of the protecting spark gap.

On the other hand, if the time-lag of disruptive strength of the insulation of the apparatus is shorter than that of the protecting spark gap, the latter would not give effective protection against momentary voltages, even if at steadily applied voltage it discharges much below the disruptive strength of the apparatus.

An investigation of the disruptive effects produced by transient voltages was therefore undertaken. Some of the results found with air and with dry white paraffine oil, are given in this paper.

For producing single high-voltage impulses of very short duration, the method used by Professor Creighton in his study of lightning phenomena was applied: a continuous voltage is impressed upon the primary coil of a high-voltage transformer, through a non-inductive resistance. During the rise of the continuous current in the transformer primary, a voltage impulse is induced in the (high-potential) secondary of the transformer. The height of the voltage impulse and its duration are determined by the continuous voltage of the supply circuit, and by its resistance. The total energy input to the transformer is determined by its inductance L and the final value of the continuous input i_0, as the energy of the magnetic field of the transformer, $\frac{i_0^2 L}{2}$.

II. Method of Tests

To study small amounts of energy at high voltages, a small transformer had to be used, and considerable difficulty was first found in avoiding oscillations due to the internal capacity of the transformer winding. The arrangement of circuits shown in Fig. 1 was found satisfactory in giving single high-voltage impulses of low energy, free from oscillations. Constant watchfulness however was necessary, as the least poor contact or leak in any of the circuits immediately created an oscillation and thereby produced erratic results.

In Fig. 1, T is a high-potential transformer, with ratio of turns 1 to 300. Its high potential leads connect to the spark gap G. The screw thread of G is 1.6 mm. per turn, so that $\frac{1}{16}$ turn changes the gap by 0.1 mm.

At the low potential side, the transformer is shunted by an adjustable non-inductive resistance r_3, and connected through a

second adjustable non-inductive resistance, r_2, to the continuous supply voltage e_2.

As a source of direct voltage there was used a 40-ampere 440-volt mercury arc rectifier R, supplied through the reactive transformer T_1 with 60-cycle 110-volt alternating current from the city lighting system. To suppress the voltage pulsations of the rectifier, a high reactance x_1, of about $L_1 = 1.0$ henry inductance, was inserted into the circuit, and the circuit then shunted by a condenser of about $C = 25$ mf. capacity. A non-inductive resistance r_1 was shunted across the voltage e_2, and adjusted so as to give a continuous load of $i_1 = 2.5$ amperes.

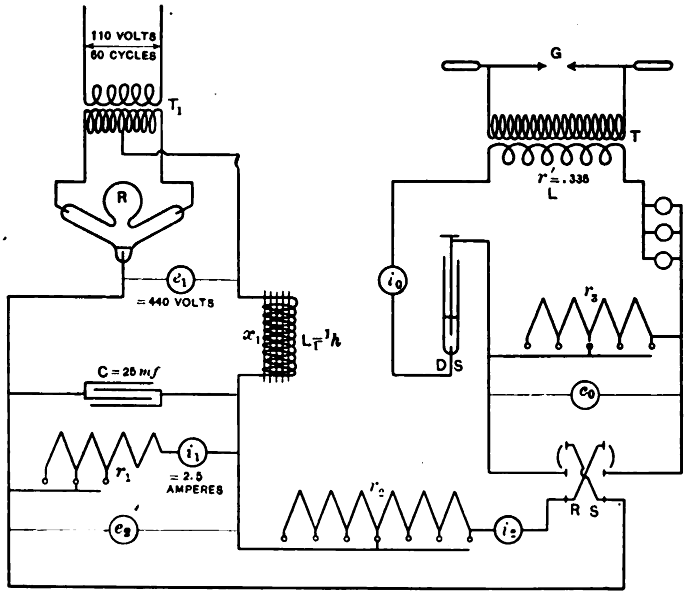


FIG. 1

In some tests, a non inductive resistance r'' was inserted, in series with the transformer. For this resistance, three incandescent lamps were used in multiple; one metallized filament lamp, and two luminous heater lamps. The combination of the positive temperature coefficient of the former, and the negative temperature coefficient of the latter gave a resistance which was nearly constant up to 4 amperes (about 400 watts), and at the same time extremely non-inductive. Its characteristic is shown in Fig. 2.

The impulse produced by closing the transformer circuit was

used, as the impulse in opening the circuit is indefinite in voltage, and usually oscillatory. The circuit was closed by a drop switch *D S* Fig. 1; a 7-mm. copper rod dropping 30 cm. into a mercury cup. As the residual magnetism of the transformer exerts a considerable effect, the impulse was always produced by closing the circuit in the reverse direction from that in which it had been closed before. For this purpose the reversing switch *R S* was inserted between the shunt resistance r_3 and the series resistance r_2.

With i_0 = 2 amperes in the transformer *T*, and an inductance L_1 = 0.75 henry, the current in the condenser *C* was 0.12 ampere. As the frequency of the pulsation is 120 cycles, this gives,

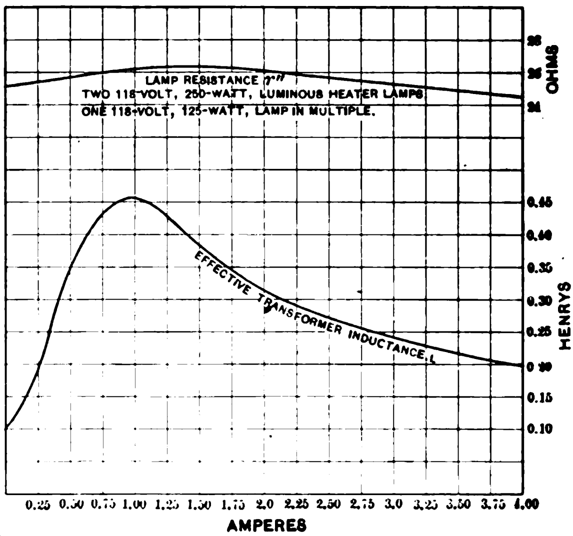


FIG. 2

for L_1 = 1.0 henry, a pulsation of 5 volts out of 440, or rather less, since part of the condenser current is due to higher harmonics. This pulsation did not extend into the transformer *T*, but the current pulsation in this transformer, read by a 1 to 1 transformer, was less than 0.01 ampere. To check the absence of any pulsation, after every set of tests the spark terminals *G* were slowly brought into contact with each other, and it was observed, whether at the moment before touching a continuous discharge was noticeable. This check was found very sensitive in discovering the beginning of any loose contact, leak, etc., in the system, before it exerted any appreciable effect on the readings.

TABLE I
October 4, 1909
Needles; Resistance

i_1	e_1	i_2	e_2	i_0	e_0
2.5	440	—	—	—	—
2.3	436	1.9	368	1.0	24
2.4	440	1.05	384	0	100
2.35	436	1.25	380	1.0	24

Dist. turns	No. of trials	No. of discharges
6	10	10
6½	10	10
7	10	10
7½	10	10
8	10	10
8½	10	10
8	10	8
9½	10	0
10	10	0
9½	10	0
9¾	10	1
9¼	10	4
9⅛	10	7
9	10	9
8⅞	10	10

Continuous discharge 0

i_1	e_1	i_2	e_2	i_0	e_0
2.4	436	1.05	384	0	100
2.35	436	1.25	380	1.0	24
2.5	440	—	—	—	-

e_0	dist. cm.
50	1.00
100	1.47
150	1.77
200	1.96
250	2.04
300	2.12
350	2.16

The method of operation was as follows: The resistances r_3 and r_2 were adjusted so that with the transformer circuit open, the voltage e_0, and with the transformer circuit closed, the current i_0, had predetermined values. All the meters e_1, e_2, e_0 and i_1, i_2, i_0 were read, with *R S* open, with *R S* closed and *D S* open, and with *R S* and *D S* closed. Then *R S* was opened, *D S* opened, *R S* closed in reverse direction, *D S* closed, while observing the gap *G*; then *R S* opened, *D S* opened, *R S* closed in reverse direction, etc., until 12 observations were made. Of these, the first two were not considered. The first setting of the gap was chosen so as to give a discharge at every impulse. Then the gap was lengthened and the tests repeated, and so on until no discharges passed. Then the gap was shortened in small steps, and again at every step 12 impulses observed, until every impulse passed. The gap terminals were next brought into contact to observe any continuous discharge, and then all the meters read once more, to insure that no change had taken place during the test. Ten seconds were allowed after every operation, to reach stationary conditions. The drop switch *D S* was never used for opening the circuit, and the mercury was frequently changed. A set of such tests is given in Table I.

By interpolation, the number of turns, that is, the length of gap, is found, at which 50 per cent of the impulses, that is, five out of ten, discharge across the gap.

Tests were made at the voltages $e_0 = 50$, 100, 150, 200, 250, 300 and 350, corresponding to the discharge voltages, by the ratio 1 to 300, of $e = 15$, 30, 45, 60, 75, 90 and 105 kilovolts, and with currents $i_0 = 0.25$, 0.5, 1.0, 2.0, 3.0 and 4.0 amperes. The complete set for $i_0 = 1.0$ amperes, of which the record of Table I is one point, is also given in Table I, and the various sets of tests made with needles in air, for $i_0 = 1.0$, are given in Table II. The different sets of tests are averaged.

TABLE II

Needles in air

e_0	$r'' = 0$ June '09	0 July '09	26 ohms Oct. '09	26 ohms Oct. '09	0 Oct. 09	Avg.
50	$d =$	—	1.00	1.00	0.94	0.98
100	—	1.46	1.47	1.44	1.50	1.47
150	1.79	1.71	1.77	1.80	1.77	1.77
200	1.94	1.92	1.96	1.92	2.00	1.95
250	—	2.08	2.04	2.01	2.09	2.06
300	2.17	2.10	2.12	2.10	2.16	2.13
350	—	2.17	2.16	2.17	2.24	2.19

An approximate theoretical discussion of the transient phenomena in the system of circuits Fig. 1 is given in the appendix. From this it follows that the transient voltage depends only upon the transformer inductance L, and on e_0 and i_0, but is independent of the resistance r in the transformer circuit. This affords a method of checking the absence of oscillations or other disturbances. The internal resistance of the transformer is $r' = 0.355$ ohm. Inserting a much larger resistance, $r'' = 25.7$ ohms, in series with the transformer circuit, should greatly decrease any oscillation in this circuit, if it existed, but should have no effect if the transient voltage is a single impulse, in accordance with the discussion in the appendix. All the tests were made with and without this additional resistance r'', and the agreement of the results of both sets of tests shows the absence of oscillations.

III. Results of Tests

Tests were made with needles, and with spheres of 3.8 cm. diameter, in air and in dry white paraffine oil. For the latter, the spark gap was arranged vertically, and surrounded by a glass vessel filled with oil.

TABLE III

Transient voltages—Dielectric strength of air

Voltage		Amperes primary supply i_0 =						
Primary volts e_0	Secondary kilovolts e	0.25	0.50	1.0	2.0	3.0	4.0	(∞)
Needles		Striking Distance in cm.						
50	15	0.41	0.75	0.98	1.10	—	1.22	1.26
100	30	0.48	0.88	1.47	1.89	—	2.31	2.73
150	45	0.50	0.97	1.77	2.44	2.68	3.14	4.45
200	60	0.515	1.02	1.95	2.88	3.32	3.88	6.83
250	75	0.52	1.05	2.06	3.22	—	4.50	9.80
300	90	0.525	1.06	2.13	3.45	4.05	5.02	13.0
350	105	0.53	1.07	2.19	3.60	4.46	5.39	16.3
Without resistance.......		1	1	3	2	1	1	—
With resistance.........		1	1	2	1	0	1	—
Spheres								
50	15	0.075	0.18	0.29	0.36	0.38	0.40	0.43
100	30	0.093	0.235	0.47	0.66	0.73	0.78	0.95
150	45	0.106	0.265	0.57	0.90	1.02	1.16	1.54
200	60	0.11	0.285	0.65	1.07	1.27	1.49	2.19
250	75	0.11	0.30	0.69	1.19	1.40	1.70	2.86
300	90	0.11	0.31	0.715	1.29	1.50	1.87	—
350	105	0.11	0.32	0.73	1.35	1.56	1.94	—
Without resistance.......		2	2	3	2	1	1	—
With resistance...........		1	1	2	1	0	1	—

The results are given in Table III and Figs. 3 and 4 for air, and in Table IV and Figs. 5 and 6 for oil. In these tables also are given the number of sets of tests, with the resistance r'', and without it, which have been averaged as discussed above.

TABLE IV

Transient voltages—Dielectric strength of paraffine oil

Voltage: Primary volts e_0	Voltage: Secondary kilovolts e	Amperes primary supply i_0 = 0.50	1.0	2.0	4.0	(∞)
Needles		Striking Distances in cm.				
50	15	0	0	0	0	0.03
100	30	0	0	0.016	0.054	0.17
150	45	0	0.025	0.064	0.21	0.49
200	60	0	0.036	0.155	0.40	0.98
250	75	0	0.049	0.235	0.54	—
300	90	0	0.055	0.28	0.64	—
350	105	0	0.061	0.30	0.71	—
Without resistance.......		1	2	1	1	—
With resistance..........		1	2	1	1	—
Spheres						
50	15	0.026	0.042	0.050	0.066	0.07
100	30	0.033	0.061	0.071	0.098	0.16
150	45	0.036	0.071	0.087	0.121	0.27
200	60	0.037	0.078	0.099	0.133	0.375
250	75	0.037	0.083	0.107	0.144	0.48
300	90	0.037	0.088	0.114	0.157	—
350	105	0.037	0.092	0.120	0.163	-
Without resistance.......		2	4	2	2	—
With resistance..........		2	4	2	2	—

For comparison, tests were made with 60-cycle alternating voltages and are given in Table V and Fig. 7, for needles and spheres, in air and in oil.

In these tests, the primary of the transformer was shunted by a constant non-inductive resistance of 30 ohms, to avoid any change of wave-shape of the terminal voltage of the transformer when varying it by a series resistance. The constancy of the transformer ratio was checked by using another like transformer as a step-down transformer. For needle points in air, the observed striking distances were identical, within the errors of

observation, with those given in the Standardization Rules of the A.I.E.E.

TABLE V

Alternating-current 60-cycle voltages—Dielectric strength

Kilovolts e maximum $= \sqrt{2} \times$ effective voltage	Striking distance in air-cm.		Striking distance in paraffin oil—cm.	
	Needles A. I. E. E.	Spheres	Needles	Spheres
5	0.40	0.125	—	0.02
10	0.81	0.27	—	0.045
15	1.26	0.43	0.03	0.07
20	1.72	0.59	0.06	0.10
25	2.22	0.76	0.11	0.13
30	2.73	0.95	0.17	0.16
35	3.27	1.14	0.27	0.20
40	3.82	1.34	0.37	0.235
45	4.45	1.54	0.49	0.27
50	5.19	1.75	0.63	0.305
55	5.98	1.96	0.80	0.34
60	6.83	2.19	0.98	0.375
65	7.75	2.41	—	0.41
70	8.70	2.63	—	0.445
75	9.80	2.86	—	0.48

In the last columns of Table III and IV, and in Figs. 3 to 6, have been added the striking distances for maximum alternating voltage, that is $\sqrt{2}$ times effective voltage, as taken from Table V and Fig. 7.

It is interesting to note in Table V and Fig. 7 the great difference in the shape of the curves of striking distances, with 60-cycle alternating voltage, in oil and in air. In oil, up to 29 kilovolts maximum, the striking distance between needle points is less than between 3.8 cm. spheres. Below 15 kilovolts, no striking distance between needle points under oil could be observed at all; the striking distance apparently was so small that the needle points could not be adjusted for a sufficiently small gap. When approaching the disruptive voltage, mechanical motion of the oil and, occasionally, the production of gas bubbles was observed, and also a noticeable time lag, so that three to five seconds had to be allowed at every voltage point before further raising the voltage; otherwise the disruptive

voltage could be considerably exceeded. It seems that electrostatic disruption in oil is a very complex phenomenon, involving mechanical motions and chemical dissociation. The oil had to be carefully dried and filtered, otherwise the results become very erratic.

In Figs. 3 and 4, the striking distances with transient voltages, between needles and 3.8-cm. spheres in air, each curve corresponds

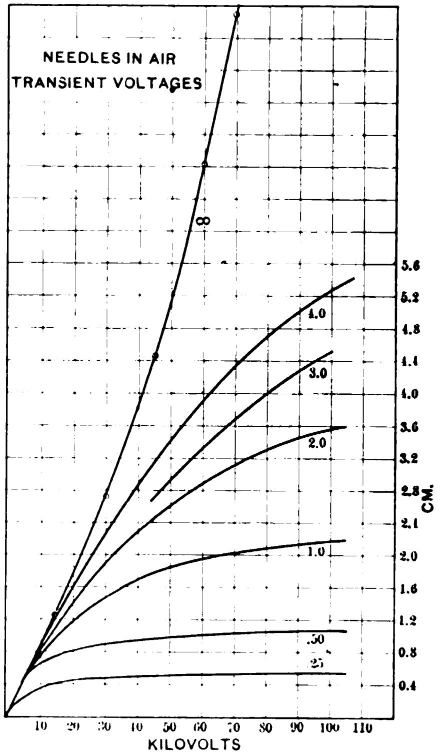


FIG. 3

to a definite current input into the transformer, that is, a definite energy value. The energy is the lower, the smaller the current and the curve for unlimited energy input, as given by a steadily applied alternating voltage, is marked by ∞.

It seems from this that the curves of striking distances with transient voltages start from the curve of unlimited energy (∞) at low voltages, but drop below this curve the earlier and the more rapidly, the smaller is the amount of available energy.

In Fig. 3, for an energy input into the transformer represented by $i_0 = 0.25$ or 0.5 ampere, the striking distance is, at 15 kilovolts, very much lower than at unlimited energy. At $i_0 = 1.0$ and 2.0 amperes it is still appreciably lower, while for $i_0 = 4.0$ amperes, it is practically the same at 15 kilovolts as with unlimited energy, but drops below at higher voltages.

All these curves of constant-energy striking distance seem,

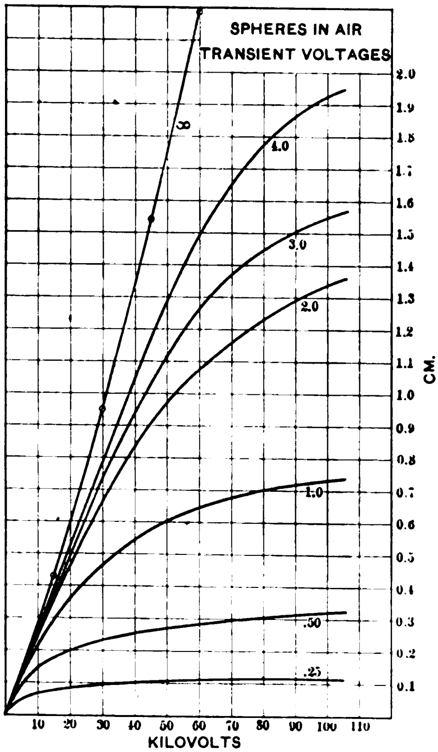


FIG. 4

for higher voltages, to approach the horizontal direction; that is, a finite limit of striking distance. For the small amount of energy available with $i_0 = 0.25$ and $i_0 = 0.5$ ampere, this final limit of striking distance seems to have been practically reached within the range of the tests, and has been fairly well approached at $i_0 = 1.0$ ampere. For $i_0 = 2.0$ amperes or more, however, the curve of striking distance is still markedly rising at 105 kilo volts.

With transient voltages, the striking distance seems to approach a finite limit with increasing voltage, and this limit is the higher, the greater is the available energy, which is behind the voltage. For sufficiently high voltage, the striking distance at limited energy becomes independent of the voltage, and merely a function of the energy back of the voltage. Thus between needle points in air, for the energy represented by $i_0 = 0.25$ ampere, 50 kilovolts gives practically the same striking

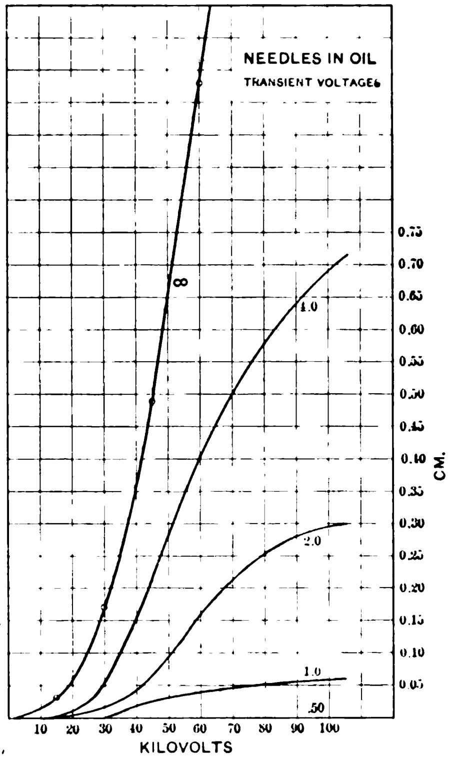


FIG. 5

distance as 100 kilovolts—a little over one-half cm., At the higher energy given by $i_0 = 0.5$ ampere, 50 kilovolts still gives nearly the same striking distance as 100 kilovolts, but the striking distance is about twice as great as at the lower energy given by $i_0 = 0.25$ amperes. At 25 kilovolts, $i_0 = 0.25$ ampere gives nearly the same striking distance as at 100 kilovolts, but $i_0 = 0.5$ ampere already gives a lower striking distance at 25 than at 100 kilovolts.

Hence the usual curve of striking distance, derived by tests with unlimited energy, does not apply at all when the voltage lasts so short time that the energy back of the voltage is limited. At 100 kilovolts, the striking distance between needle points in air is about 15 cm. with unlimited energy, but only 0.52 cm., or about one-thirtieth as much, with the limited power of $i_0 = 0.25$ ampere; and even at $i_0 = 1$ ampere, the striking distance

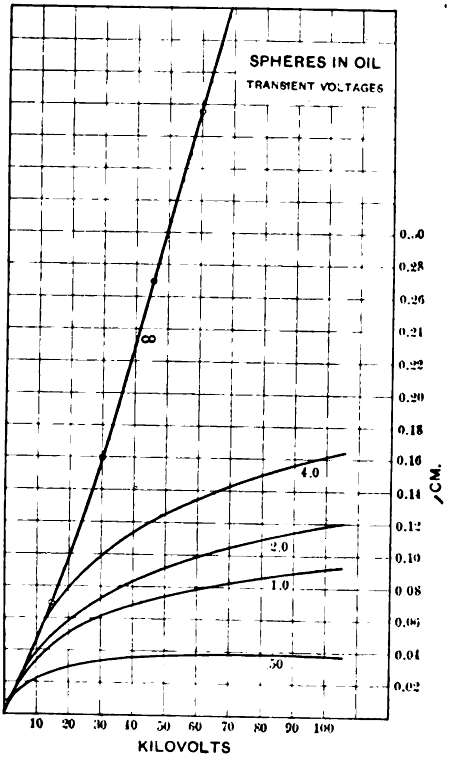


FIG. 6

is still less than 2.2 cm., or one-seventh as much as given by unlimited energy at the same voltage of 100 kilovolts.

At transient voltages of very limited energy, the striking distance becomes a function of the energy, and not of the voltage, and increases with increasing energy, but not with increasing voltage.

Between spheres in air, the effect of limited energy back of the voltage in decreasing the striking distance is similar to that

between needle points, but is greater with low values, and slightly less with higher values of energy. . That is, with the same available energy, if the energy is very small, the striking distance between spheres at transient voltage is a smaller fraction of the striking distance of unlimited voltage, than it is with needle points. This is shown by Table VI, which gives the striking distances of transient voltages as fractions of the striking distances with unlimited voltage, for needle points and for 3.8-cm. spheres in air.

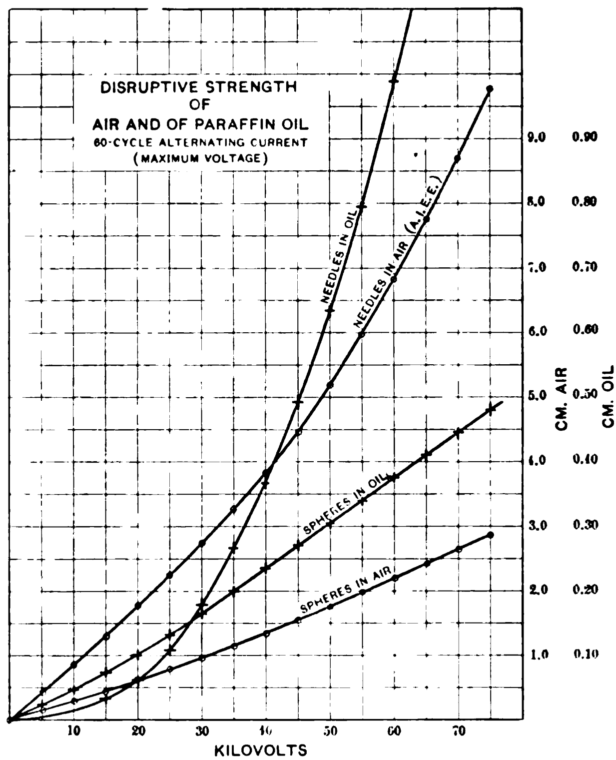


FIG. 7

Thus, if a needle gap and a sphere gap are set to discharge at the same alternating voltage, at transient voltages the discharges would always pass over the needle gap if the energy is very small, and usually over the sphere gap if the energy is large.

TABLE VI

Transient-voltage striking distances in air, as fractions of unlimited-energy striking distances

Voltage kilovolts e	i_0 = 0.25	0.50	1.0	2.0	4.0
Needles in air:					
15	$\frac{d}{\infty}$ = 0.325	0.595	0.777	0.873	0.970
30	0.176	0.323	0.538	0.693	0.845
45	0.112	0.218	0.398	0.500	0.707
60	0.706	0.150	0.286	0.422	0.567
75	0.053	0.107	0.210	0.329	0.460
90	0.040	0.082	0.164	0.266	0.387
105	0.033	0.066	0.134	0.221	0.331
Spheres in air					
15	0.174	0.418	0.675	0.837	0.930
30	0.098	0.247	0.495	0.695	0.823
45	0.069	0.172	0.370	0.585	0.754
60	0.050	0.130	0.297	0.488	0.680
75	0.038	0.105	0.242	0.416	0.595
Spheres in oil:					
15		0.372	0.60	0.715	0.940
30	—	0.207	0.382	0.445	0.613
45	—	0.134	0.263	0.322	0.448
60	—	0.099	0.208	0.264	0.355
75	—	0.077	0.173	0.223	0.300

With spheres in oil, the behavior at transient voltages is similar as with spheres in air, as seen from Table VI, except that the decrease of striking distance with limited energy is very much greater with oil than with air, and at the lowest value of energy, that given by i_0 = 0.25 ampere, no discharges at all could be observed; that is, the energy apparently was not sufficient to break down even the smallest oil film.

This means that the "time lag of disruptive strength" of oil is much greater than that of air, and an oil gap requires a greater amount of energy, to be punctured, than an air gap set for the same alternating voltage (*i.e.*, voltage of unlimited energy.)

Thus a sphere gap of 0.6 cm. in air, and a sphere gap of 0.1 cm. in oil, discharge at the same voltage of 20 kilovolts, if unlimited power is back of the voltage. With a single impulse of transient voltage, limited in energy to that given by i_0 = 2.0 amperes, the air gap discharges at 27 kilovolts, while the oil gap requires

62 kilovolts. To discharge at 30 kilovolts, the energy given by $i_0 = 4.0$ amperes is required for the oil gap, while the air gap requires only the energy given by about 1.75 amperes; that is, much less energy. It therefore follows, that an air gap, set for such distance as to protect oil insulation against voltages of unlimited energy, also protects against transient voltages; but inversely, an oil gap, even if set to discharge at an alternating voltage much lower than that which air insulation would safely stand, would not protect against transient voltages if of sufficiently limited power.

To some extent, similar relations exist between the needle gap and sphere gap in air. As seen from Table VI, for low values of energy, an air needle gap would protect a sphere gap against transient voltages, but not inversely; while for higher values of energy, a sphere gap would protect a needle gap against transient voltage, but not inversely. The differences for higher values of transient energy are relatively small compared with those for lower values, and in general, therefore, it seems that the needle gap in air is safer than the sphere gap in protecting against transient voltages. Thus spark gap terminals are preferably corrugated or knurled.

Very different and strange are the curves of striking distance of transient voltages, with needle points in oil, as shown in Fig. 5. The lower energy values, corresponding to $i_0 = 0.25$ and $i_0 = 0.5$ ampere, give no appreciable striking distance at all, even above 100 kilovolts. At $i_0 = 1.0$ ampere, no appreciable striking distance exists at 30 kilovolts, but the lowest voltage at which an appreciable though very small (0.025 cm.) striking distance is observed, is at 45 kilovolts. Even at the highest energy values used in the test, 15 kilovolts give no striking distance. With needle points in oil, the transient voltage curve does not approach the alternating voltage curve ∞ at low voltage (as seems to be the case in Figs. 3, 4 and 6). It has an incurve at low voltage like the alternating curve ∞, but at higher voltages, the higher the voltage the lower the energy. Such needle points in oil seem to require the highest amount of energy; that is, they give the greatest time lag of discharge, far greater than spheres in oil. At 60 kilovolts, the striking distance between needle points in oil is, at $i_0 = 1.0$ ampere, less than 1/27 of what it is with unlimited energy, while with spheres in oil it is about one-fifth, and with needles as well as spheres in air, approximately three-tenths.

There appears thus an essential difference in the relation between needle points and spheres as discharge terminals in oil and in air, and the difference is of the same general character for transient voltages as for alternating voltages. This difference is somewhat similar in its nature to the difference between brittle and ductile bodies in their action against mechanical forces.

IV. Striking Distances with Infinite Transient Voltages

The striking distances of transient voltages of constant energy seem, with increasing voltage, to approach a constant value, as seen in Figs. 3 to 6. An attempt was therefore made to find a mathematical expression for this upper range of the curve, at which the striking distance begins to become independent of the voltage and a function of the energy. The two simplest curves, which respresent asymptotic approach to a straight line, are the exponential and the hyperbola. The shape of the curves in Figs. 3 to 6 is different from the characteristic of the exponential, and an equilateral hyperbola was thus tried.

Assuming that d_0 = the striking distance, reached at infinite transient voltage, and the approach to this value is hyperbolic at higher voltages. This would give the curve

$$e\,(d_0 - d) = c^2 \qquad \textbf{(1)}$$

where d is the striking distance at transient voltage e, and c is a constant.

If now e_1 and e_2 are two voltage values, and d_1 and d_2 their corresponding striking distances, we get, by substitution in equation (**1**)

$$e_1\,(d_0 - d_1) = c^2$$

$$e_2\,(d_0 - d_2) = c^2$$

and from this, by eliminating c^2

$$d_0 = \frac{e_2\,d_2 - e_1\,d_1}{e_2 - e_1} \qquad \textbf{(2)}$$

By this equation (**2**), from any two points of a curve a value of d_0 can be calculated, and if the values of d_0, calculated from

the different pairs of points of the same curve of striking distances agree, this would show an agreement of the observed curve with an equilateral hyperbola.

This calculation was made by using the observations from 45 to 105 kilovolts, and the results are given in Table VII.

TABLE VII

Striking distances d_0 at infinite transient voltage

$$e\,(d_0 - d) = c^2;\quad d_0 = \frac{e_2 d_2 - e_1 d_1}{e_2 - e_1}$$

	i_0	$e_1 = 45$ $e_2 = 60$	45 75	75 90	90 105	kilovolts kilovolts
Needles in air:	0.25	0.56	0.54	0.55	0.56	avg. d_0 = 0.55
	0.5	1.17	1.17	1.11	1.13	1.14
	1.0	2.49	2.50	2.48	2.55	2.51
	2.0	(4.20)	4.58	4.60	4.50	4.56
	4.0	(6.10	6.98)	7.42	7.61	7.5
Spheres in air:						
	0.25	—	—	—	—	Avg d_0 = 0.11
	0.5	0.345	0.36	0.36	0.38	0.36
	1.0	(0.89)	0.85	0.84	0.82	0.84
	2.0	(1.58)	1.67	1.79	1.71	1.72
	4.0	2.48	2.54	2.72	2.36	2.52
Needles in oil:						
	1.0	(0.067)	0.11	0.085	0.096	Avg. d_0 = 0.09
	2.0	0.43	0.555	0.505	0.42	0.46
	4.0	(0.97)	1.1	1.14	1.13	1.13
Spheres in oil:						
	0.5	—	—	—	—	Avg. d_0 = 0.037
	1.0	(0.909)	0.103	0.113	0.116	0.111
	2.0	(0.135)	0.139	0.149	0.156	0.148
	4.0	(0.169)	0.188	0.222	0.199	0.203

Four values of d_0, corresponding to successive sections of the empirical curve, are given, and as seen from Table VII, these four successive values of d_0 agree with each other very well, especially in air; that is, they show no regular deviation from the averages, which are also given in Table VII. A marked deviation from the average is found only for the lower voltage sections of the curves of high energy; that is, those parts at which the curve is fairly close to that of unlimited energy, and was to be expected in this

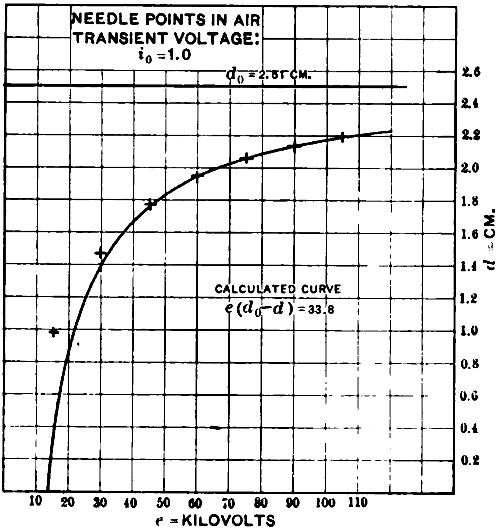

NEEDLE POINTS IN AIR
TRANSIENT VOLTAGE:
$i_0 = 1.0$
$d_0 = 2.51$ CM.
CALCULATED CURVE
$e(d_0 - d) = 33.8$
d = CM.
2.6 2.4 2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2
10 20 30 40 50 60 70 80 90 100 110
e = KILOVOLTS

FIG. 8

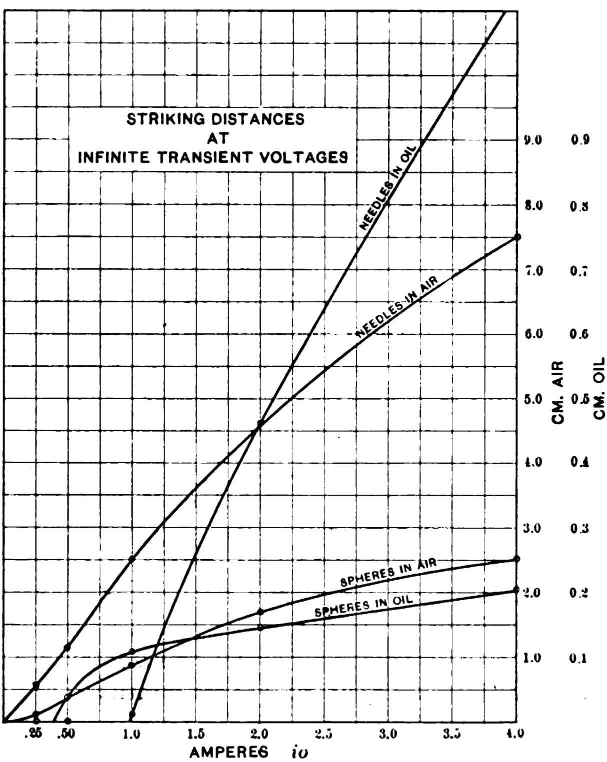

STRIKING DISTANCES
AT
INFINITE TRANSIENT VOLTAGES
NEEDLES IN OIL
NEEDLES IN AIR
SPHERES IN AIR
SPHERES IN OIL
9.0 0.9
8.0 0.8
7.0 0.7
6.0 0.6
5.0 0.5
4.0 0.4
3.0 0.3
2.0 0.2
1.0 0.1
CM. AIR
CM. OIL
.25 .50 1.0 1.5 2.0 2.5 3.0 3.5 4.0
AMPERES i_0

FIG. 9

case. In averaging, these values have been omitted and are given in brackets in Table VII.

It seems, from Table VII, that the agreement of the striking distance curve of transient voltages with the equilateral hyperbola, is more than a mere coincidence, and seems to be based on some physical law. Especially close is the agreement with the air curves, while the oil curves are more irregular, as was to be expected from the complex nature of the phenomena occurring in oil, as discussed above.

As illustrating this, there is plotted in Fig. 8 the equilateral hyperbola calculated for needle points in air, the energy being $i_0 = 1.0$ ampere, and the observed values are marked by crosses. As seen, from 45 kilovolts upwards, the agreement is practically perfect.

The striking distances d_0 at infinite transient voltage, as a function of the current i_0, which supplies the available energy, are plotted in Fig. 9, the curves for air being plotted to 10 times the scale of the curves for oil, as in Fig. 7.

Since the energy available at the spark gap is not a simple function of the current input into the transformer, but related thereto by the magnetization curve of the transformer, no simple expression can be expected to represent the curves of Fig. 9.

V. Energy of the Discharge

An attempt was made to estimate the energy of the discharge from the excitation curve of the transformer. This excitation curve is given in Table VIII, and plotted in Fig. 10, with the maximum values of the exciting current as abscissæ, and the maximum values of the 60-cycle alternating voltage as ordinates.

Up to $i = 1.0$ ampere, the values of Table VIII are derived by alternating current, since in this range, below saturation, the ratio of maximum to effective value of the exciting current is very closely $\sqrt{2}$. The higher values are determined by ballistic test with continuous current, in the following manner: The transformer is shunted by a constant non-inductive resistance, and a milliammeter is included in this shunt. The throw of the milliammeter needle is observed when impressing upon the transformer various values of direct current. First, a series of readings was taken with the non-inductive shunt so adjusted as to give good deflection within the range in which the excitation curve of the transformer had been determined by alternating current, and plotted in Fig. 11 as the calibration curve of the

TABLE VIII

Excitation of transformer and energy

60 Cycles

i	e	$\Sigma i \Delta e = s$	i	e	$\Sigma i \Delta e = s$	i	e	$\Sigma i \Delta e = s$
0.05	2.1	0.052	0.75	119.6	54.2	1.9	233	189.4
0.1	4.7	0.247	0.8	130.1	62.4	2.0	237	197.2
0.15	7.9	0.647	0.85	140.6	71.1	2.2	245	214.0
0.2	12.2	1.397	0.9	151.0	80.2	2.4	253	232.4
0.25	18.3	2.767	0.95	161.5	89.9	2.6	260	249.9
0.3	26.4	4.99	1.0	171.8	100.0	2.8	267	268.8
0.35	36.2	8.18	1.1	185.0	121.0	3.0	273	286.2
0.4	46.2	11.93	1.2	195.0	132.5	3.2	279	304.8
0.45	56.5	16.50	1.3	203.0	142.5	3.4	284	321.3
0.5	66.9	21.24	1.4	210.0	152.0	3.6	289	338.8
0.55	77.4	26.8	1.5	216.0	160.7	3.8	294	357.3
0.6	88.0	32.9	1.6	221.0	168.4	4.0	299	376.8
0.65	98.5	39.4	1.7	225.0	175.0			
0.7	109.1	46.6	1.8	229.0	182.0			

TABLE VIII

Correction for residual magnetism

i	e	$\Sigma i \Delta e = s$	e	$\Sigma i \Delta e = s$	e	$\Sigma i \Delta e = s$	e	$\Sigma i \Delta e = s$
$i_0 =$		0.25		0.5		1.0		$\geqq 2.0$
0.0	-8.0	0.0	-40	0	-124	0	-168	0
0.05	-4.2	0.095	-26	0.35	- 68	1.40	-104	1.60
0.1	0	0.410	-14	1.25	- 41	3.42	- 58	5.05
0.15	+5.8	1.135	- 4	2.50	- 20	6.04	-26	9.05
0.2	11.5	2.135	+ 7	4.42	- 4	8.84	- 6	12.55
0.25	18.3	3.675	17	6.57	+10	11.99	+10	16.15
0.3			26.4	9.15	23	15.57	23	19.73
0.35			etc.		34	19.15	34	23.31
0.4					46.2	23.73	46.2	27.89
					etc.		etc.	
s, by above table =		2.767		4.99		11.93		11.93
Difference =		0.908		4.16		11.8		15.96

TABLE IX
Energy of magnetization

i_0 = (amperes) =	0.25	0.5	1.0	2.0	3.0	4.0
$s = \Sigma i \Delta e$ =	2.767	21.24	100.0	197.2	286.2	376.8
Correction for residual magnetism =	0.908	4.16	11.8	15.96	15.96	15.96
Per cent =	32.8	19.6	11.8	8.1	5.6	4.2
Total s =	3.675	25.4	111.8	213.2	302.2	392.8
Energy, in joules:						
$W = \frac{s}{2\pi f} = \frac{s}{377}$ =	0.00975	0.0676	0.298	0.566	0.803	1.044
=	0.01	0.068	0.30	0.566	0.80	1.04

(f = 60 cycles.)

ballistic test. Then the non-inductive resistance was adjusted to bring the deflection for the range from 1.0 ampere to 4.0 amperes, on the curve Fig. 11, and from this curve, from the known

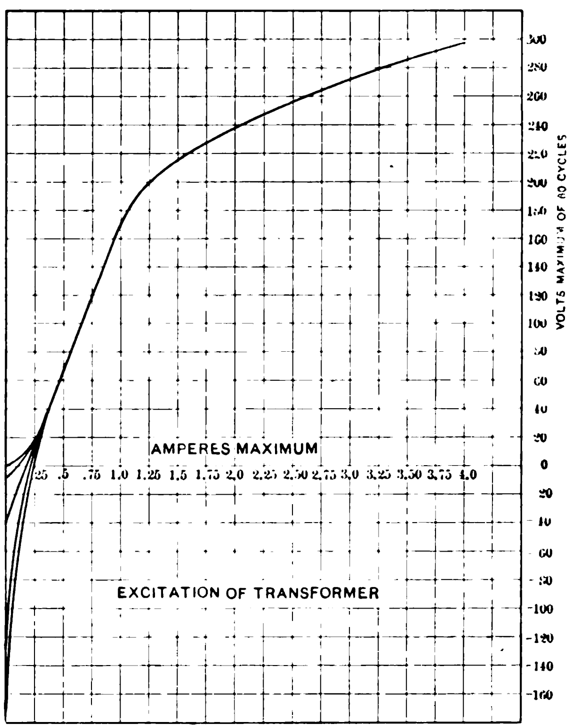


Fig. 10

voltage at 1.0 ampere, the voltages corresponding to higher currents were calculated.

By energizing the transformer in the same direction as before, and in the reverse direction, the residual magnetism was determined, and thereby the correction of the energy for residual magnetism estimated.

The energy input into the transformer was calculated from the area between the excitation curve Fig. 10 and the vertical axis, as

$$W = \frac{\Sigma i \triangle e}{2 \pi f}$$

where $\triangle e$ is the difference between two successive voltage values, i the average current corresponding to $\triangle e$, and thus $\Sigma i \triangle e$ the desired area. $f = 60$ cycles.

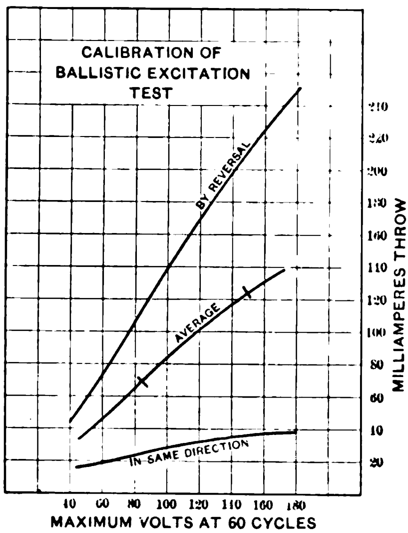


FIG. 11

This calculation is given in Tables VIII and IX, together with an approximate correction for residual magnetism.

It is interesting to note, that the energy values used in the tests, varied from a minimum of 0.01 joule (or watt-seconds) to a little over 1 joule. It must be considered, however, that this represents the total energy input into the transformer. These energy values, therefore are the upper limit of the energy which is sufficient to break down the spark gap, and considered in this manner, it is remarkable to see how very small an amount of energy is sufficient to produce disruptive effects.

Comparing the striking distances at infinite transient voltage (that is, at voltages which are so high, that the striking distance has become independent of the voltage, and a function of the energy only), as given in Table VII, with the corresponding values of energy, in Table IX, would give the striking distance as a function of the energy. The data are not sufficient to determine with any degree of exactness the dependence of the striking distance on the energy, since the energy values represent the total energy, and not that available at the spark gap. By comparing, however, the curves of striking distance for oil, and those for air, with the same terminals, relative values of the disruptive energy of oil and of air can be derived.

The striking distances between 3.8-cm. spheres in air can be represented approximately by

$$W = 0.3\, d_0^{1.5}$$

and those between the same spheres in oil by:

$$W = 10\, d_0^{1.5}$$

where d_0 = striking distance at infinite transient voltage, in cm., and W = energy in joules used for producing the transient voltage.

From this it would follow that an air gap requires only 3 per cent of the energy required by the same oil gap, to start a discharge; or inversely, that it takes 33 times as much energy to electrostatically disrupt oil as its takes with air.

The curves for air and oil calculated from above equation are given in Fig. 12a and b with the striking distance between spheres d_0 as abscissæ, and the energy W was ordinates. The observed values are marked by crosses, but as seen, the agreement is not very close.

The striking distance curve with transient voltages between needle points in oil is so different in shape from that in air that it does not appear probable that both can be expressed by the same equation, as required for comparing the disruptive energy of air and oil. The striking distance curve between needle points in oil, seems to reach the zero value ($d_0 = 0$) at a finite value of energy ($W_0 = 0.235$ joule), and if this is the case, it would mean, that with needle points in oil, about one quarter joule is re-

quired to start the discharge, irrespective of distance and voltage, and only the remainder of the energy is available for disrupting

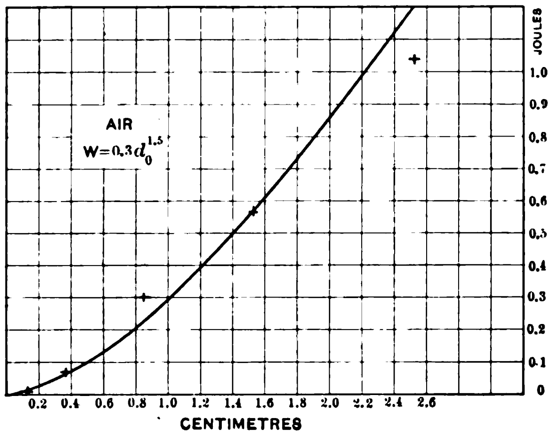


FIG. 12A

the path of the discharge. This however requires further investigation.

The striking distance curve with infinite transient voltages

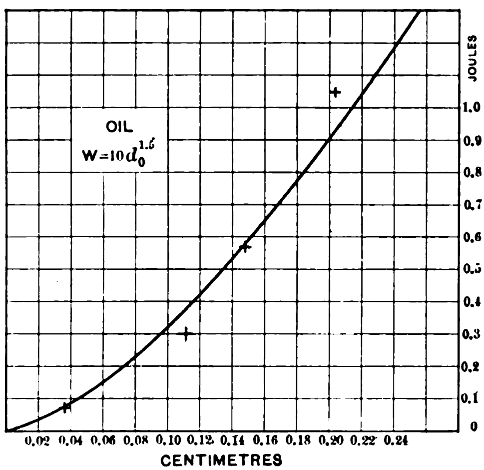


FIG. 12B

between needle points in air can be expressed approximately by the equation

$$W = 0.063\, d_0^{1.5}$$

and that between needle points in oil, by the equation

$$W = 0.235 + 0.72\, d_0$$

From this it would also follow, that a spark gap between 3.8-cm. spheres in air requires about 5 times as much energy as a spark gap of the same length in air between needle points.

In table X are given the ratios of the striking distances $\left(\frac{\text{distance in oil}}{\text{distance in air}}\right)$ for needle points and for 3.8-cm. spheres.

As seen, with needle points the ratio increases with increasing transient voltage, and also increases with increasing energy. With spheres, the ratio first decreases, and then increases again, and seems to reach a minimum for some intermediate values of voltage and of energy.

TABLE X

Ratio of striking distances = $\frac{\text{distance in oil}}{\text{distance in air}}$

kilovolts	amperes = 0.25 joules = 0.01	0.50 0.068	1.0 0.30	2.0 0.566	4.0 1.04	∞ ∞
Needles						
15	0	0	0	0	0	0.0238
30	0	0	0	0.0085	0.0234	0.0623
45	0	0	0.0141	0.0262	0.067	0.110
60	0	0	0.0185	0.0538	0.103	0.144
75	0	0	0.0238	0.0730	0.120	—
90	0	0	0.0258	0.0812	0.128	—
105	0	0	0.0278	0.0833	0.132	—
∞	0	0	0.0358	0.101	0.151	—
Spheres						
15	0	0.144	0.145	0.139	0.165	0.163
30	0	0.141	0.130	0.108	0.126	0.168
45	0	0.136	0.125	0.097	0.104	0.182
60	0	0.130	0.120	0.093	0.089	0.172
75	0	0.123	0.120	0.090	0.085	0.168
90	0	0.119	0.124	0.088	0.084	—
105	0	0.116	0.126	0.089	0.084	—
∞	0	0.103	0.132	0.086	0.081	—

VI. Conclusions

The disruptive discharge through a dielectric requires not merely a sufficiently high voltage, but requires a definite minimum amount of energy.

The disruptive discharge does not occur instantly with the application of voltage, but a finite though usually very small time elapses after the application of voltage, before the discharge occurs. During this time the disruptive energy is supplied to the dielectric. This time may be called the " time lag of the discharge ".

The disruptive energy of oil seems to be about 30 times greater than that of air, and that of solid dielectrics probably is still greater. An oil gap thus requires a greater time before it discharges than an air gap, but even an air gap does not discharge instantly. An air gap thus can protect an oil gap against momentary voltages, but not inversely.

With limited available energy, the striking distance increases slower with increasing voltages, and drops below the striking distance with unlimited energy; and ultimately the striking distance becomes entirely independent of the voltage, and merely a function of the energy.

At constant energy, with increasing voltage, the striking distance seems to approach constancy in a hyperbolic curve.

The voltage at which the striking distance has become practically independent of the voltage, is the lower, the more limited is the amount of available energy.

From the available data, the following approximate empirical equations for the energy W, in joules, used for a disruptive discharge over a distance d_0, in cm., are derived:

Needle points in air	$W = 0.063\, d_0^{1.5}$
3.8-cm. spheres in air	$W = 0.3\, d_0^{1.5}$
Needle points in dry white paraffine oil	$W = 0.235 + 0.72\, d$
3.8-cm. spheres in dry white paraffine oil	$W = 10\, d^{1.5}$

The investigation of the disruptive effects with transient voltages, *i.e.*, limited energy, is of theoretical interest, as it may lead to a clearer understanding of the nature of the disruptive discharge. It also is of industrial importance, as most of the abnormal voltage phenomena occurring in electric circuits are transient, *i.e.*, of limited energy, and an effective control and protection of electric systems therefore will require a knowledge of the action of transient voltages as well as permanent voltages. Very little however is known on the disruptive

effect of transient voltages, and further extensive investigations on this subject are therefore desirable.

APPENDIX

Approximate Equations of Test Circuit

Let $r = r' + r''$ = total resistance of transformer circuit, including lamp resistances, etc., and L = inductance.

Let e_0' = voltage impressed upon this circuit, with initial value e_0.

i = current in this circuit, with final value i_0

e = voltage induced in the transformer.

From Fig. 1 we have

$$e_2 = e_0' + r_2 i_2 \tag{1}$$

$$e_0' = e + r i \tag{2}$$

$$e_0' = r_3 (i_2 - i) \tag{3}$$

$$e = L \frac{d i}{d t} \tag{4}$$

Eliminating e_0', e, i_2, and substituting

$$R^2 = r r_2 + r r_3 + r_2 r_3 \tag{5}$$

gives

$$L \frac{d i}{d t} + \frac{R^2}{r + r_2} i - \frac{r_3}{r_2 + r_3} e_2 = 0$$

and since, at the moment of starting, $t = 0$

$$i = 0, \text{ hence } \quad e_0 = \frac{r_3}{r_2 + r_3} e_2 \tag{6}$$

the equation becomes

$$L \frac{d i}{d t} + \frac{R^2}{r + r_3} i - e_0 = 0 \tag{7}$$

This is integrated by

$$i = A \varepsilon^{-a t} + B \tag{8}$$

Substituting (8) in (7) gives

$$a = \frac{R^2}{(r+r_3)\ L} \tag{9}$$

$$B = \frac{e_0\ (r+r_3)}{R^2} \tag{10}$$

Since for $t = 0$, $i = 0$, we have, by substituting (9) and (10) in (8)

$$A = -B = -\frac{e_0\ (r+r_3)}{R^2} \tag{11}$$

Since for $t = \infty$, $i = i_0$, we have, by substituting in (8)

$$B = i_0 \tag{12}$$

hence, from (11) and (9)

$$A = -i_0 \tag{13}$$

$$a = \frac{e_0}{i_0} \tag{14}$$

thus

$$i = i_0 \left\{ 1 - \varepsilon^{-\frac{e_0}{i_0 L} t} \right\} \tag{15}$$

and from (4)

$$e = e_0\, \varepsilon^{-\frac{e_0}{i_0 L} t} \tag{16}$$

hence, for $t = 0$

$$e = e_0 \tag{17}$$

that is, the ratio of transformation holds for the initial transient voltage.

The time integral of voltage is

$$E = \int_0^\infty e\,dt$$

$$= i_0 L \tag{18}$$

and the equivalent duration of the transient voltage

$$t_0 = \frac{E}{e_0} = \frac{i_0 L}{e_0} \tag{19}$$

As seen, all resistances, r, r_2, r_3 are eliminated except insofar as they are contained in e_0, the initial voltage, and i_0, the final current.

The above equations are approximate only, since they assume e_2 and L as constants.

The values of t_0 are, for

i_0 =		0.25	0.50	1.0	2.0	3.0	4.0 amperes.
L =		0.194	0.354	0.455	0.314	0.242	0.198 henry
e_0 =	50	t_0 = 0.97	3.54	9.10	12.6	14.5	15.8 milli-secs.
	100	0.48	1.77	4.55	6.3	7.2	7.9 " "
	150	0.32	1.18	3.03	4.2	4.8	5.3 " "
	200	0.24	0.88	2.27	3.15	3.6	3.95 " "
	250	0.19	0.71	1.82	2.5	2.9	3.2 " "
	300	0.16	0.59	1.52	2.1	2.4	2.6 " "
	350	0.14	0.51	1.30	1.8	2.1	2.3 " "

that is, a time varying from 0.00014 to 0.0158 seconds.

A paper presented at the 245th meeting of the American Institute of Electrical Engineers, New York, March 11, 1910.

(*Subject to final revision for the Transactions.*)

TESTS OF AN ILGNER ELECTRIC HOIST

BY R. R. SEEBER

In the copper mining district of northern Michigan a fair-sized mine usually operates two or more shafts along the strike of the lode, these shafts being usually at least a thousand feet apart. The tonnage to be hoisted from each shaft is large, —from 13,000 to 25,000 tons per month. The hoisting engines, used are generally steam-driven, non-condensing, duplex engines with Corliss valves, supplied by steam from separate boiler plants where the distance between shafts is great.

In an attempt to centralize power plants and secure central station economies, the Winona Copper Company installed an electric hoist of the Ilgner type, with Ward Leonard control. A brief description of this plant appeared in the *Engineering and Mining Journal* of July 19th, 1909 . The only point of variation from the simple Ilgner set lies in the connection of two generators to a single induction motor by flexible couplings. These generators serve motors which operate hoisting drums at separate shafts viz. No. 4 shaft Winona, and No. 1 shaft, King Philip. The hoist for No. 4 shaft is about 1,700 ft. from the power plant and in this building the motor-generator set is placed. No. 1 King Philip hoist is 1,500 ft. from the motor-generator set. The equipment of the motor-generator set is as follows:

In the middle of the set is a 12-pole, 450 h.p, 600-rev. per. min. 2,080-volt, three-phase, 60-cycle, variable-speed, induction motor, connected on each side to a 20-ton flywheel which is 10 ft. in diameter, and to a 6-pole, 170-kw, 575-volt, interpole, direct-current generator. On each side of the shaft is placed a separate exciter which delivers current at 125 volts. The lubrication of the four main bearings that support the flywheels

and direct-current generators is supplied by two sets of oil pumps, belt-driven from the shaft.

The hoist motors are 6-pole, 200-h.p., 430-rev. per. min. 550-volt motors, and are shunt-wound. The fields, both of this motor and the direct-current generators are excited by current from the exciter on the motor-generator set, which is kept at a constant voltage of 125 by voltage regulators. The current in the hoist motors is varied and reversed through controllers of the usual railway type, placed in the field circuit of the generators. The first point on the controller operates a contactor which closes the main circuit from the generator to the motor.

The alternating current for operating the motor-generator passes through a regulator which automatically varies the resistance in the rotor of the motor-generator set in proportion to the demand of the motor for current.

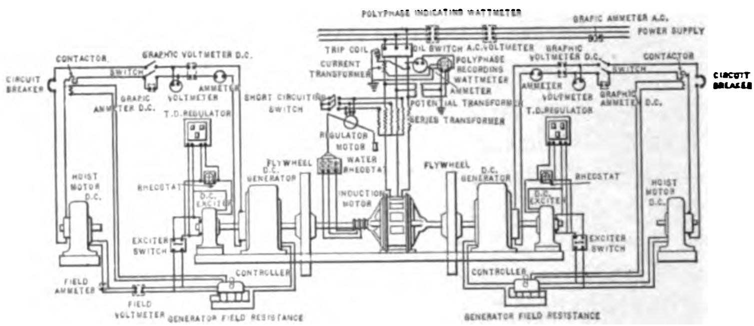


FIG. 1.—Diagram of connections of motor-generator set

During February, 1910, detailed tests of this set were made to determine the performance under varying conditions, and to procure coal-to-rock ratios to compare with ratios for steam hoists under similar conditions.

On the switchboard controlling the set, the following instruments were already installed:

Alternating current indicating ammeter.
Recording wattmeter.
Direct-current ammeter and voltmeter for each direct current generator.

In addition for the purposes of this test, the following instruments were installed, as shown on the diagram Fig. 1:

Two 600-0-600 direct current graphic voltmeters, one in each generator circuit.

Two 800-0-80 direct current graphic ammeters, one in each generator circuit.
One 125-ampere alternating current graphic ammeter.
One 125-volt direct current indicating voltmeter.
One 100-ampere direct current indicating ammeter.
One indicating wattmeter with necessary current transformers.
One 600-rev. per min. tachometer.

No. 4 shaft Winona is served by the hoist drum in the same building as the motor-generator set. This is an old duplex steam hoist, with the cranks disconnected. The motor drives the old crank shaft through gearing. The drum is seven ft. in diameter and holds 1,500 ft. of rope. The rope is 1⅛ in. in diameter and weighs two lb. per ft. No. 4 shaft is double-compartment and the skips work in balance. Because at present very little hoisting is being done in this shaft, only the south skip is used for loads and the north skip carries 2,100 lb. of rock to lessen the starting moment. At the time of the test the north skip had filled with ice, so that the total counterbalancing weight was 3,300 lb. This caused more power to be used for the lowering of the south skip than for hoisting it. The loaded skip weighed 5,400 lb. Of this amount, 3,300 lb. is counterbalanced leaving only 2,100 lb. of rock and the hoisting rope as the net load.

No. 1 shaft King Philip is operated by an old geared steam hoist, with the cranks disconnected and the crankshaft geared to the motor in the same manner as at No. 4 Winona. The drum is five ft. in diameter and holds 1,200 ft. of one-inch rope, weighing 1.58 lb. per ft. The shaft is built with two compartments but only one skip is running, leaving the hoist unbalanced.

The skips in both shafts are the same and weigh 2,900 lb. each. Each holds 2.7 tons of rock when full. The test was conducted under normal working conditions and the loads varied. During the time of test, a man was stationed at the brace of each shaft to observe the fulness of the skips. The average distance of the rock from the top of the skip was estimated for each load and a correction was applied.

The work at present being done at these shafts is comparatively small, because only development work is under way. Since all reliable information that I had concerning the operation of steam hoists was at a hoisting rate of 12,000 to 15,000 tons per month, we arranged to hoist from each shaft for an hour at near this rate. During all this time the curve-drawing instruments were in operation and gave accurate records of each operation. Readings

of the alternating-current wattmeter, voltmeter, and ammeter were taken every five seconds. The starting and stopping time of each of the hoist movements was taken, and the nature of the load recorded. The speed of the motor generator set was taken at regular intervals.

The following tabulations show the levels from which rock was hoisted during this one-hour test, also the total number of skips, total rock hoisted from each level, the average load, the distance from the level to the dump on the incline of the shaft, 70 deg. and the product of load and distances; also totals and averages. This rate of hoisting corresponds to about 19,000 tons per month or rather more than the rate of the steam hoists with which it is compared.

WINONA SHAFT

Level	Skips	Load		Distance	Load distance
		Tons	Average		
9th	5	11.9	2.4	918 ft.	10924
10th	4	10.2	2.5	1018 ft.	10384
11th	4	10.2	2.5	1118 ft.	11403
12th	3	7.7	2.6	1218 ft.	9379
	16	40		1052 ft.	42090 At 600 ft. equivlent to 70.15 tons

KING PHILIP SHAFT

Level	Skips	Average load		Distance	Load-distance
		Tons	Average		
5th	1	2.0	2.0	425′	850
6th	6	13.2	2.2	524′	6917
7th	-	—	—	623′	—
8th	5	10.2	2.04	729′	7436
9th	3	4.95	1.65	832′	4119
10th	4	9.45	2.36	932′	8807
11th	-	—	—	1034′	—
12th	3	7.4	2.5	1135′	8399
—	22	47.2	2.15	Average 774	36528 At 600′ equivalent to 60.88 tons

Adding the total tons hoisted at Winona to the total tons hoisted at King Philip during the same period gives an equivalent of 131

tons hoisted from a depth of 600 feet in a 70-deg. incline. The total kilowatt-hours taken by the motor-generator set during this hour was 211. This output was determined by reading an indicating wattmeter every five seconds and taking the average. The power necessary to hoist one net ton of rock from a depth of 600 ft. on the incline was 1.61 kw-hr.

Tests of our power plant, under present light-load conditions, have shown that it requires about four pounds of coal to produce one kilowatt-hour delivered on the switch board of the motor-generator set. The amount of coal required to hoist a ton from this distance is therefore 6.44 lb. giving a coal-to-rock ratio of 1 to 310.

Winona........	70.15 tons	
King Philip....	60.88 "	
	131.03 "	hoisted at 600 ft. depth on 70 deg.

211 kw-hr. taken by set.
1.61 kw-hr. per ton.
6.44 lb. coal per ton at 4 lb. coal per kw-hr.
Coal-to-rock ratio = 1 to 310.

For purposes of comparison with the steam hoist conditions, I have tabulated the results in rock hoisted and kilowatt-hours taken by the motor-generator set for an average day.

16 hours	211 kw.	=	3,376 kw-hr.
4 "	80 kw.	=	320 "
1 hour	55 kw.	=	55 "
		Total of	3,751 kw-hr.

3 hours shut down.
Total of 24 hours.

Rock is hoisted during but 16 hours of the time, making the total rock hoisted for both shifts 2,096 tons; or 1.79 kw. hr. are required to hoist one net ton of rock from a depth of 600 ft. on a 70 deg. incline. This makes the coal-to-rock ratio for the above conditions 1 to 279.

The theoretical value of kilowatt-hours per ton hoisted taken from Fig. 21 of the paper presented by Messrs. Rushmore and Pauly* is 1.7 kw-hr. Taken from the curves in Fig. 22 for the 8,000-ft. hoist, this value is 1.55 kw-hr.

At the D shaft of the Champion Copper Company, a 24-in. by 60-in. duplex Corliss engine operates a double conical hoist drum. The shaft inclination is about 70 deg. the skips working

* A. I. E. E. PROCEEDINGS, April 1910.

in balance. The boiler plant supplies the rock house engine and dry in addition to supplying the hoist. For the first four days of November, 1905, the boiler plant supplied the hoist alone. The coal-to-rock ratio for these four days, at 600 ft. average depth, was 1 to 154. Using a percentage of fuel burned for the rock hoisted, obtained from results of this four days' test (68.4 per cent to hoist), the ratio for the remainder of November was 1 to 185, showing gain by better boiler load. For December of the same year on the same basis, the ratio was 1 to 166. The average load of rock was 2.1 tons, the total amount hoisted in a month being about 15,000 tons.

At the Winona mine, No. 3 shaft was operated in June, 1907, by a separately-fired boiler plant. The hoist is a duplex geared hoist with a rolling valve. The shaft is inclined 70 deg. from the horizontal and the skips work in balance. The average load of rock was about 2.1 tons. In June, the coal-to-rock ratio at 600 ft. depth. figured as before, was 1 to 124. In August and September, 1907, this hoist was supplied from a larger plant, the hoist being 15 to 20 per cent of the whole load. The distribution of coal which we made gives a ratio of 175 to 200.

The following tabulation compares these ratios:

Electric hoist, two shafts, Winona; coal-to-rock ratio 1 to 279.
Champion *D* hoist; steam (alone); coal-to-rock ratio 1 to 154.
Champion *D* hoist, with rockhouse; coal-to-rock ratio 1 to 185.
Winona No. 3 hoist, steam (alone); coal-to-rock ratio 1 to 124.
Winona No. 3 hoist, steam, (central plant)—coal-to-rock ratio 1 to 175, to 1 to 200.

I feel satisfied from these figures that, even with steam generated in a central plant, a coal-to-rock ratio of 1 to 200 is about all that can be expected from steam hoists of this type, under the given conditions. This shows a coal saving by the electric method of 25 per cent over the steam method.

Fig. 2 shows the operation of the motor-generator set and both hoist motors for a typical section of about nine minutes length, taken from the one-hour test. The curves here shown will serve to describe most of the operation. The top curve shows the alternating current input plotted from five-second readings of the indicating wattmeter. The average for the nine minutes is 208.25 kw. or slightly below the average input for the hour.

The second curve shows the speed of the motor generator set, the extreme variation being from 440 to 480 rev. per. min. during this period.

The next three curves show the volts, amperes, and kilowatts output of the direct-current generator driving the No. 1 King Philip motor.

The last three curves show the volts, amperes, and kilowatts

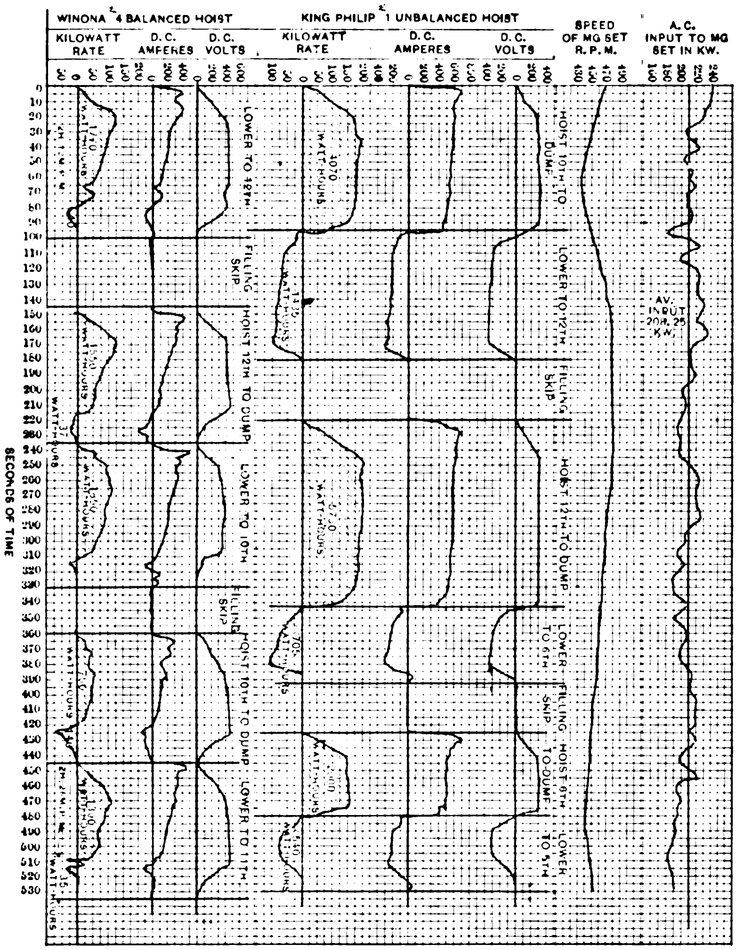


FIG. 2.—Operation of motor-generator set

output of the direct-current generator driving the Winona No 4 hoist for the same period.

Where electricity is used for hoisting, the main reason for using an Ilgner fly-wheel set is to take the peak loads off the power station. How well this is accomplished is shown by comparing

the input curve of the diagram with the two curves of direct-current output. Incidentally this method utilizes the energy of a descending unbalanced skip, the motor acting as a generator and restoring energy in the fly-wheel. For the King Philip hoist, unbalanced, the amount thus restored is comparatively large, varying from 20 per cent to 35 per cent of the energy required to hoist the loaded skip from the corresponding level. This variation is due to variation in the loading of the skips. On the Winona hoist, balanced, the amount of energy thus restored is

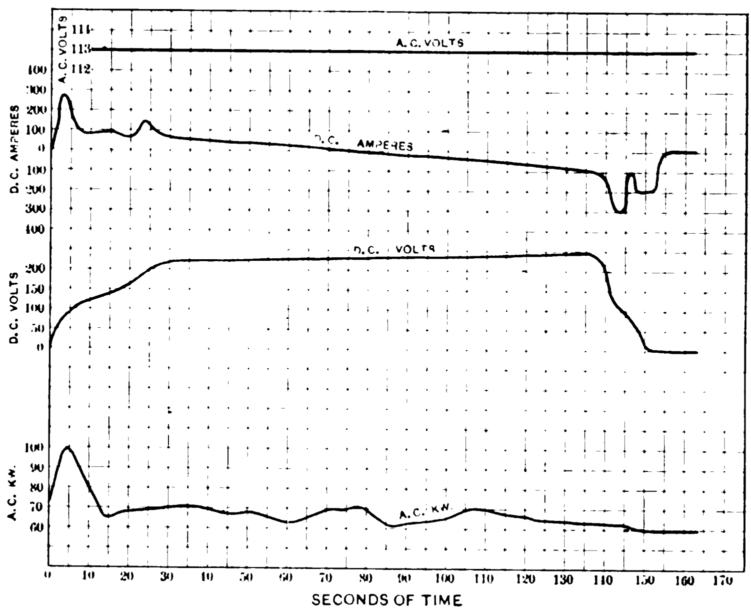


Fig. 3.— Restoration of energy

very small and occurs only when the motor is used as a brake at the close of the hoisting period.

The restored energy for both cases is shown on the shaded areas below the line. An interesting example of this restoring action is shown (Fig. 3) on Winona No. 4 hoist, where men are being hoisted on the south skip. Energy is required at starting but the demand gradually decreases and at about the 8th level the weight of the descending north skip counterbalances the ascending skip. During the remainder of the hoisting period energy is being stored in the fly-wheel.

Where a double compartment shaft can be used and the skip and rope can be counterbalanced by duplicates in the other compartment, the counterbalancing skip being ready for a paying load on reaching the bottom, it is obviously not economy of power to use any other system of restoring the energy of the descending skip. The efficiency of any other system will be very low compared to the efficiency of the counterbalancing skip where the only losses are friction and air resistance.

Fig. 4 shows the current output of the King Philip generator when hoisting a full skip from the 12th level, and the energy restored to the set when lowering the same skip still full. This was done twice, as shown.

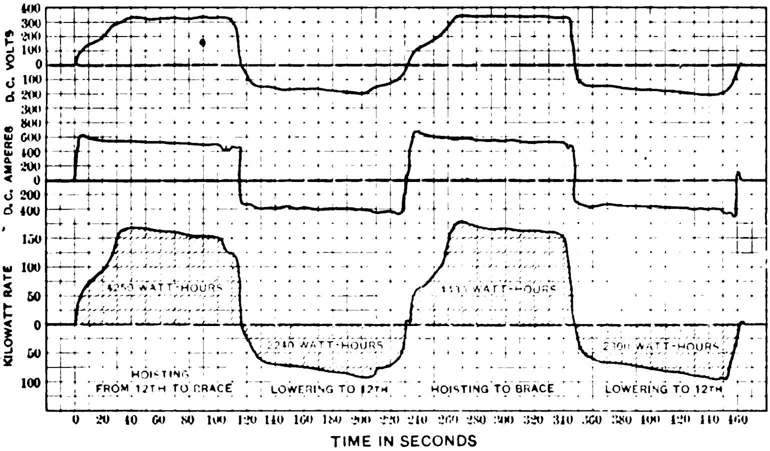


FIG. 4.—Energy expended in hoisting and lowering unbalanced hoist

The watts used in hoisting the first time were 4,250; watts returned lowering were 2,243, showing an efficiency of restoration of 52.8 per cent. The watts used hoisting the second time were 4,430; the number of watts returned lowering the second time was 2,300, showing an efficiency of restoration of 51.9 per cent.

Fig. 5 shows the decreasing speed of the motor generator set, after the power is shut off on Saturday nights. About three hours are required for the set to come to rest.

Fig. 6 shows the acceleration of the skip and the rope speed for the hoisting period.

The greatest disadvantage of the Ilgner system is a constant loss in windage and bearing friction of the motor-generator set

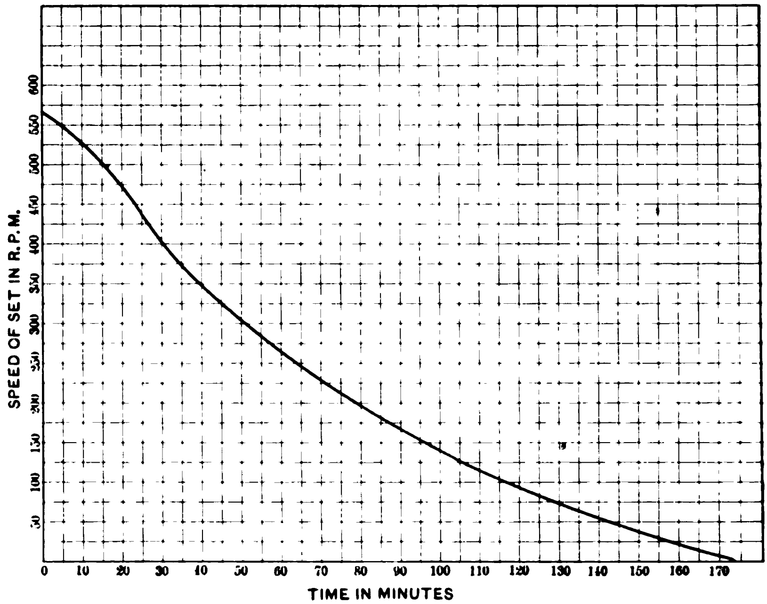


FIG. 5.—Retardation of motor-generator set

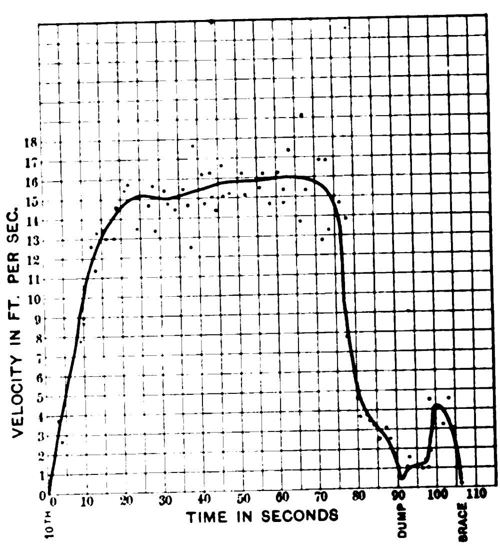


FIG. 6.—Velocities of hoisting

itself. Observations have shown this loss for the set at this plant to be very nearly 55 kw. This loss can be reduced materially by casing the fly-wheels. When the work done by the hoist is large enough to make the proportion of this constant loss small, an Ilgner fly-wheel set adds fuel saving to the saving of labor, etc., due to the centralization of the power plant.

The use of this system enables us to dispense with two boiler plants and their firemen. It would have been necessary, also to build larger boiler plants, with railroads and coal trestles to serve them. The hoists themselves handle the skips much better than the steam hoists, starting from rest very smoothly. The large amount of repair work necessary on a reciprocating engine is also done away with.

Discussion on "Modern Automatic Telephone Apparatus," New York, February 11, 1910

(Subject to final revision for the Transactions.)

Chairman Maver: It may be of interest to note that in telegraphy two general systems are employed, namely, manual telegraphy, and automatic telegraphy. The first relates to the hand transmission of messages and the second to the machine transmission of messages. In telephony we also have manual and automatic systems, so called, but these relate to the manner in which subscribers' circuits are coupled into one metallic circuit at the exchange and have nothing to do with the transmission per se of communications, which is of course effected by the subscribers' voice. It is of course well known that in the present day practice of telephony each subscriber in a given district is connected with central by two wires, the terminals of which, in the manual system, are led into a switch board in the exchange and normally end there. There is in the circuit of these wires a relay which closes a circuit containing a small incandescent lamp which lights up when the subscriber lifts his telephone receiver from the hook, thereby indicating to the attendant operator in the exchange that a connection is desired. Upon listening in and ascertaining the number of the desired subscriber the operator by means of jacks and cords performs the operation of placing the lines of these subscribers in a through metallic circuit, ready for intercommunication. In a large exchange one operator can attend to the calls of about two hundred subscribers. In automatic telephony on the other hand the operation of coupling up the circuit of a calling subscriber with any other subscriber is performed automatically in the exchange by selecting and connecting apparatus controlled by impulses of electric current established primarily by the calling subscriber.

The question of automatic telephony is perhaps not a very active issue with us in the East at present, but it is decidedly so in the western part of this country, where it is in quite extensive operation, and also to a smaller extent in the eastern part. For instance, New Bedford and Fall River, Massachusetts have automatic telephone exchanges that have been in successful operation for the past eight or ten years.

I am sure, that we all feel under obligations to Mr. Campbell and to the company with which he is associated, for their courtesy, in not only presenting the paper, but also in bringing before us this model working exhibit of the apparatus, and on behalf of the Telegraphy and Telephony Committee, I desire to express our hearty appreciation of this courtesy.

Before calling for discussion, I will ask Mr. Campbell to kindly show us the manner in which the ringer arrangement acts in this apparatus and also to point out the location of the Keith line switch.

(Mr. Campbell then briefly described the apparatus and gave further demonstrations.)

Ralph W. Pope: A discussion of a system of this kind naturally brings up a comparison with other systems. We have been through various discussions of that kind in this room, that have sometimes raised the temperature appreciably. This is a case, however, where we are not called upon to discuss the question of whether or not the apparatus works, because we know that it does work. I think that our vision can be cleared sometimes by taking a reverse view of the conditions. There is always some doubt as to whether an automobile is better than a horse, but if we always had had automobiles, would we use horses to supersede them? So, if we had always had the automatic telephone system in use, would we be talking about introducing the manual system as an improvement.

I have been much gratified, in reading over the paper, to see the modest claims made by the author, and to note that he has refrained from saying that the automatic system will answer in every place and under all conditions. In a certain sense, I am quite familiar with it, so far as lapse of time is concerned. I was Chairman of the Committee on Telegraphy and Signalling at the World's Fair in Chicago in 1893, when we examined the Strowger system which was at that time on exhibition. I believe that it did not receive an award, because of its crude construction, and it was felt that it did not appear equal to the claims made for it; and I think I am safe in saying that it was not then in use to any great extent. Rather curiously, we considered at that time the question whether it was really adapted to large cities, and it seemed to be the opinion that it was better adapted for the smaller cities and the question of its suitability for the larger cities had not been proved. Since 1893 its utility has been proved, and here in New York, where we are supposed to be able to get the best of everything there is, and to see everything that is worth seeing, it remained for the American Institute of Electrical Engineers to have a working exhibit of this automatic telephone system for the public to come and examine.

Last summer I visited the Pacific coast, and there, for the first time since my experience in Chicago some seventeen years ago, I had the opportunity of examining the automatic system in operation in Portland, Oregon. It was rather a novel experience to be in that exchange of about eight thousand lines, and to see the connections, or rather hear them, being made throughout the room, with practically no one in attendance at all; and another thing I learned there in Portland, from our own members, who were simply subscribers to the automatic system, was that from their experience they preferred the automatic system to the manual system, on account of its certainty of conveying the signals, and not giving the wrong numbers. Another point, which was new to me, and which was first made known to me by a subscriber who was an electrical man and had an automatic exchange system connected with his residence, was

that occasionally a lineman came looking for trouble on the circuit before the subscriber knew that there was any trouble. It appears that in the exchange, instead of waiting for trouble to be reported from the outside, they can locate the trouble on the line from the exchange and remove it promptly before the subscriber is aware that there is any trouble.

Another interesting device connected with the system, which was called to my attention, was the meter for registering the calls. It appears that in some of the cities on the coast the franchise requires that the telephone exchange system must be on a meter basis, that is, that the subscriber must pay by the number of calls. The result is that the companies are obliged to meter the system, and the meter not only registers completed calls, but it discards " service " calls and discards calls that are not completed, so that the meter actually registers only the calls that are to be paid for.

From Portland, Oregon, I went to San Francisco, and there the Home Telephone Company's system was in process of construction. I visited the main exchange and several of the branches, and it is quite certain and evident that the people who are building that system have faith in the automatic telephone exchange, for the reason that it is one of the best and most expensively constructed systems that I have ever visited—all the exchanges are fire-proof, the wires are underground, led up in lead-covered cables, and as far as I could see no expense has been spared to make the installation first-class in every particular.

It must be remembered that the manual system may be properly divided into two classes, so far as the subscriber is concerned—the subscriber may work direct with the exchange or he may work through a private branch exchange. In the course of my experience I have found that the perfection of the manual system depends very largely on the disposition, the voice and the attention of the particular operator that has charge of the section with which one is connected. I feel that with the introduction of a private branch, while the operator usually has less on her mind, that we do not receive the short and petulant answers, and the impression that we are trespassing on the time of somebody, and we had better be quick about it, that we get when we are connected with the main exchange. Right here, while this has no bearing particularly on the paper, I think it is well for all of us to remember, and I presume we have criticised it—that when the operator at the exchange repeats back the number wanted, we can rarely understand what the number is, and if you wish to correct it, the operator has gone, so that that time is practically lost, and I understand that the practice has been abandoned in some of the exchanges for that reason. It may have been due to Mr. Campbell's Chicago voice that he brought with him to-day, but when he undertook to make a telephone connection from my office, he succeeded twice in getting the wrong number, and we began to think that the

number was wrong in the book, but I believe he finally succeeded in getting connection with the subscriber. I am free to confess that this was a rather bad exhibit to make of the manual system to a gentleman who came here with this exhibit we see to-night.

Chairman Maver: I will make some additional remarks, and read one or two communicated discussions, to one of which Mr. Pope has referred. As Mr. Pope has said, Mr. Campbell is quite modest in his claims, and therefore, even if one were disposed to be critical, not much opportunity is afforded. Mr. Campbell presents his apparatus almost as though it were on trial, whereas it is in actual operation on a large scale in over fifty cities and towns in this country, embracing a total of 250,000 subscribers.

Mr. Campbell refers to the somewhat crude apparatus first employed in the system which he has described in his paper, in which the calling subscriber pushed buttons corresponding to the call number of the called subscriber. There were, however, more cumbersome ways than this employed in some of the early automatic telephone systems, to one of which (the Callendar automatic telephone) I may refer, as it may help to show the manner in which our predecessors sometimes groped about to reach a desired point; just as our successors will no doubt observe that we of 1910 have only been groping in many things, where we imagine we have reached the acme of perfection. The Callendar automatic telephone was, I believe, in limited use for some time in this country. By reason of its awful and wonderful design it is worthy of passing mention. Each subscriber's wire was led into the central exchange in such a manner and so arranged with regard to certain mechanism that when a subscriber called he was first connected with a "numerical receiver." This numerical receiver had a movable grooved arm, in the form of a rail, which was adapted to make contact with certain other rails as required. In a suitable receptacle were kept a number of metallic balls, which were allowed at the proper moment to roll into the traveling rail from which they were delivered to the subscriber's rail. The subscribers' rails were placed across certain conductors normally not touching. At each point on a rail, where it crossed a conductor, a trap was placed in the rail. When any one of these traps was opened a metallic ball coming down the rail fell through the trap and made contact with the conductor below. Each subscriber was allotted a rail and a cross conductor. When, then, a certain subscriber desired a certain other subscriber, he would give the necessary impulses of current which would bring the traveling rails into position with the rails of the desired subscriber, and the metallic ball would then pass from this receptacle on to the subscribers rail up to the point where a trap was found open, when the ball fell through and made connection with the subscriber's cross-connected conductor. In short, by the mechanism employed in this system, the subscribers, by a process of selection, were finally automatically

connected and they were isolated from other subscribers while thus connected. When through, one or other of the subscribers pressed a release button; the traps were closed and the balls were returned automatically to their receptacle, ready for other calls.

It is to be feared that if automatic telephony depended on a system involving contact by movable rails and rolling balls it would be within bounds to predict that hopes of its ever attaining commercial usefulness would be meagre.

One of the most frequent objections that was offered to automatic telephony in its early days was that the multiplicity of contacts necessarily employed would prevent its successful operation, and it used to be pointed out that whereas in a manual exchange for 5,000 subscribers there are, for instance, something like 133,000 pairs of contacts, in an automatic exchange for 5000 subscribers there might be 1,000,000 pairs of contact in the first selectors alone. The introduction of the Keith line switch, however, has reduced the number of such contacts in the automatic exchange by perhaps eighty per cent. Even, however, before the introduction of the Keith switch, comparatively little trouble was experienced by the great multiplicity of contacts in the automatic exchange; and from actual observation it is my experience that such troubles are quickly indicated by supervisory signals.

Another point that may be mentioned is that the wear and tear on the automatic apparatus is inconsiderable. This is partly due to the fact that much of the apparatus is not in operation more than 2 to 5 per cent of the time. Apart from this fact, actual experiments with certain automatic apparatus, where the mechanism was operated by machinery over 1,000,000 times, shows that the wear of the parts was not perceptible.

There is no doubt that the large amount of apparatus and the multiplicity of contacts employed in the automatic coupling of subscribers circuits tends to the occurrence of troubles that are unknown in the manual systems. An instance of these troubles of comparatively frequent occurrence is the "off normal" troubles, due to a failure of some part of the apparatus to complete its full function or to return to normal position. This for example may be due to sticking of the wipers in the bank contacts, to imperfect contacts, etc. In the common battery system of the manually operated exchange there are numerous delicately adjusted relays operated automatically, and in the multiple switchboard of the same system there are countless contacts, jacks and cords, subject to handling in no delicate manner, and all conducing more or less to the production of defects, but it may fairly be assumed that the occurrence of contact and apparatus troubles in the manual system is less frequent than in the automatic system.

It is, however, a fact that while the occurrence of such troubles is comparatively frequent in the automatic system, nevertheless the methods adopted to promptly announce or indicate the oc-

currence of defective operation to the attendants, by supervisory lamps and other signals, are so efficient that in the large majority of cases the defects are discovered and rectified before the subscribers concerned are aware that such troubles have existed. Further, the attendants become so accustomed to the rhythmic sounds of the apparatus in the process of making normal connections that their ear detects any abnormal operation of a piece of apparatus almost before the supervisory signal can indicate the defect. By reason of this ability of the attendants to recognize non-completed calls they are frequently able to assist in completing a call. This is done by cutting in on the calling subscriber's line to inquire the number of the called subscriber, on learning which the attendant rotates the various parts of the apparatus manually as required for the proper connection. I believe that a daily average of about 16 such " assist " calls has been noted in one large automatic exchange. In consequence also of this ability of the attendants to forestall and to quickly rectify apparatus troubles in the exchange, the disadvantage of the occurrence of such troubles loses much of the weight it might otherwise possess. Obviously, in this as in many other systems, electrical and mechanical, constant vigilance is the price of good service.

The advantages rightly claimed for automatic telephony are numerous. Of course the most important one is that of dispensing with the need of operators at the exchange, not only in effecting a large saving in operating expenses, but also by solving the " girl " problems in the exchanges, which involve training the girls, their leaving the service abruptly when trained, the necessity for resting rooms in the exchanges, etc. These problems, together with the difficulty in obtaining operators suitable for the work in certain localities, have frequently been the deciding factors in determining the adoption of an automatic exchange. There is also the further important advantage that, in the aggregate, much time is saved in the automatic method of connecting, and more especially of disconnecting, subscribers, which admits, among other things of the use of a lower percentage basis of apparatus and of trunking circuits.

It is also evident that the percentage of " wrong number " calls is, in the nature of things, much higher in manual than in automatic exchanges, the difficulty in hearing numerals by telephone, and the repetition from voice to voice accounting for much of this confusion. There is perhaps no greater single cause of annoyance to subscribers, and of loss of valuable time in effecting connections to a telephone company, than this matter of " wrong number " calls. The claim for secrecy in the automatic system does not have much weight with me although it appears to do so with the general public. It is my experience that the operator in a busy manual exchange has little time and less inclination to listen to the subscribers conversation.

As the result of a wide investigation of automatic telephony

in the United States and Canada, I can confirm the claims made for automatic telephony by its advocates as to its popularity with the general public where it is established, especially that basic feature of the art which enables the subscriber to make his own calls without the intervention of an operator.

E. A. Mellinger: A field for further development of the automatic system is suggested by Mr. Campbell's reference to small exchanges. Since a very large proportion of the telephones in use in the country are in exchanges of 500 lines or less, the development of a simple inexpensive switchboard designed especially for use in the small town exchange would go far toward making the telephone universal.

Aside from the economic consideration pointed out by Mr. Campbell, the chief problems which present themselves as affecting the practical operation of small automatic exchanges using the present type of equipment are the maintenance of the battery supply and the care of the apparatus. These problems are successfully solved in the case of private installations, as is indicated by the number of these exchanges in use in government and state institutions, industrial plants, mines, etc.; but in these instances ample facilities exist for charging storage batteries and a competent electrician is usually at hand to attend to trouble which might arise, or to make needed adjustments or changes. The average town exchange of one hundred lines or thereabouts is at a serious disadvantage with respect to these items, which it would appear might be at least partially overcome by the use of simple equipment constructed especially for this kind of service.

Concerning the economic disadvantages of small automatic exchanges, it would be of interest to some to know how large an exchange must be to justify the use of automatic equipment as now installed, and what factors are to be considered in making a comparison. A consideration of the data available from a number of both manual and automatic exchanges indicates that the automatic begins to show an economy at about 500 lines. In a typical modern manual plant of this size there are employed eight operators at an annual expense of $2,160. As against this, an automatic plant of 500 lines has one operator or clerk and a switchman, totaling $1,100.00 per annum, thus showing a net average in operation over the manual exchange of $1,060.00.

Assuming that the automatic equipment, telephone and switchboards, will cost $8,500.00 in excess of the manual equipment, and allowing on this excess investment six per cent interest and six per cent for depreciation, we find that these annual charges amounting to $1,020.00 are just about equivalent to the saving effected in maintenance and operation. The other factors entering into consideration total about the same in each case, and would not appreciably affect the result, except that the smaller floor space required for the automatic switchboard would be an item in its favor.

Local conditions in small exchanges vary so greatly that this figure of 500 lines cannot, of course, be taken as authoritative. Public automatic exchanges of fewer than 200 lines have been operated satisfactorily and economically, but it is probable that under present conditions the average exchange of less than four or five hundred lines cannot afford to install automatic equipment except that the greater popularity of automatic service might be considered as an economic advantage as it undoubtedly is in most instances where competition exists.

E. L. Lehman: Mr. Campbell's description of the working of the automatic telephone appears to be well set forth, but what about the apparatus that does not work or cannot report when out of order? After all, it is the efficiency of repairs and cost of maintenance that satisfies the subscriber and lowers the rental charge. The fundamental requirements of operation to be met in maintaining both the manual and the automatic systems may be briefly summed up as follows: The " busy " and " trouble back " signals, " don't answer," " receivers off," and line and trunk troubles. In the manual switchboard any trouble occurring with the "busy" or "trouble back" signals would be noticed instantly a connection was put up. " Don't answer " reports are given to the calling subscriber if the called subscriber does not answer. In the case of a business subscriber or the calling subscriber insisting that the called subscriber is within hearing of his telephone a report of " can't raise " is given to the wire chief who makes a test on the line and quite often finds the line in trouble, in which case repairs may be quickly made.

Another important item in maintaining telephones is the loss of incoming calls to subscribers who have left their receivers off the hook. In a manual exchange of about 6,000 stations, a percentage of about 1.5 per day is comparatively small, and the percentage to total calls outgoing and incoming would amount to one-quarter of one per cent. Yet if these stations had their receivers off all day the loss in outgoing and incoming calls would amount to the considerable sum of 1,200, or three per cent of the total calls for the day. It is safe to say that, with the present system of plugging out on the manual system, very few calls are lost, as the subscriber is reminded to hang up his receiver by a high frequency tone thrown on the line.

Relative to lines in trouble; operators are quick to report swinging grounds, receiver circuits open due to tips out, etc., poor transmission, etc., while the plugging-out system takes care of a large percentage of instrument, line, cable and office trouble, such as shunts, grounds and open circuits. Trouble on trunk lines, office to office, may be intermittent yet are quickly noticed by an operator.

One more comparison occurs to me, namely, the calling of private branch exchange numbers or any subscriber that has two or more lines, generally numbered in consecutive order. In the manual operation, if such a subscriber is called, and the number

called is busy, the connection will be put upon the next available trunk line, while the automatic subscriber would probably have to look up the number and call until a trunk line not busy was found.

Query: Can the automatic system be controlled to such an extent that a subscriber's station may not be out of order over a period of two or three hours before the fact is known by the switchman?

H. W. Pope: Some fourteen years ago I met Mr. Campbell at Augusta, Georgia. One of the first systems of automatic telephony was introduced in that city, with one selector, as I recall it, to each line. It was a very crude affair, and the wonder to me was that it worked at all, and I presume it was very largely due to the care of the man in charge of it that it did work.

There are some things that this paper hardly touches upon—in fact, you would hardly expect it to—and these are the questions of maintenance and of depreciation. Now, I have an idea that the cost of maintenance is a very large item in connection with the automatic system. I am laboring under the impression that it requires a skilled man for every thousand telephones, which would be quite an item in a large exchange, for skilled men do not work for nothing, and this system is particularly applicable to large exchanges. Of the matter of depreciation, I have no reliable knowledge. I understand there has been a system in operation in Fall River for something like ten years, which has shown a depreciation not to exceed, I think that of the manual board. Mr. Campbell has refrained from saying anything in this connection that would lead to any argument or criticism.

Another thing which occurs to me is this; a good system, whether manual or automatic, should be one that is available for all people, for the illiterate and for the blind, or for any person that can speak the language of the country in which the telephone system is operated. Now, the automatic system especially as regards the requirements for the placing or transmitting of the call, does not meet these conditions as easily or as simply as the mere act, in the manual system, of lifting the telephone from the hook. I do not know how you could handle this automatic system in the dark, unless you were very familiar with the transmitting apparatus, and that is quite an essential thing, so far as its use in residences is concerned. In case of danger, fire, burglary, or anything of that kind, the mere fact that if, in the manual system, you take the telephone off the hook, attention is called to the fact that something is the matter, is of very great advantage. I read only yesterday or the day before of a case of suicide, where the information was gained from the telephone; the woman who committed suicide left the telephone off the hook and they heard her groan. That is a newspaper story, but I can imagine cases where emergencies might arise whereby attention would be called in this manner. Of course, it is a small thing, but it is worth considering in

connection with automatic systems. A blind man is certainly prevented from using the automatic telephone, and we have many blind people who use the telephone.

I do not think there is much in the contention as to the rapidity of the signalling to the central office. Of course, the subscriber in working the automatic system is busily engaged in whirling around the transmitting devise to the proper point, and he does not realize the time he is consuming. While he is doing that, in the City of New York you put in a call and get an answer. That may not apply everywhere, but it applies here. Mr. Campbell says in his paper that "generally speaking" it is more profitable than the manual system. I infer from that that sometimes it is not, and I think that is quite a question. From what I have learned and seen, and I have seen quite a good deal of it, I have always considered it an expensive system to maintain; but I do find that it gives great satisfaction to the subscribers and it eliminates a good deal of difficulty in connection with the wrong number. Of course, with the automatic system, the wrong number comes right back to the customer every time. In the manually operated system the subscriber looks in the book and finds 3700 and gives 3800; he does not realize that he is making the mistake and is prone to blame it on the operator; but the fact is that the customers probably make more mistakes than the operators do.

Charles A. LeQuesne, Jr.: I ask Mr. Campbell to explain if this system can be adapted to the use of private branch exchanges in connection with city exchanges; and also, what provisions is made for handling pay station calls, and whether in using a pay station telephone, it is necessary to first deposit your coin before being able to operate the calling mechanism, and, having done so, is the coin returned if you do not get the connection?

A. R. Sawyer: In 1904 when I became connected with the Michigan Agricultural College I found a campus of 25 acres or more with about 18 buildings scattered over it and no method of communication between them. I recommended to the Board of Control the adoption of a system of communication that would facilitate intercourse between the heads of the departments and save much time, the arguments for which need not be repeated. I saw that what we needed was a telephone system which would be intercommunicating for every office on the grounds and would be cheap enough in maintenance cost so that everybody could have one. I also soon realized that most of the offices should have connection with one or both of the Lansing exchanges.

After studying the matter I decided to recommend the automatic system, which was adopted by the Board of Control after due investigation. The outcome was that we put in an automatic telephone system sufficient to accommodate one hundred telephones, with three trunk lines connected to the city exchange in Lansing. The automatic system was selected because, once

installed, the management would hear virtually nothing more of it in the way of running expenses. A manual system would necessitate adding to the college pay roll at least three operators as well as at least part of a man's time to keep the exchange in order, whereas the automatic system would need only part of a man's time to keep it in shape and we would have good service twenty-four hours a day and seven days in the week. At that time neither of the exchanges in Lansing gave us satisfactory service and it was my desire if we were going to put in a system that the outcome should be satisfactory telephone service. As a result, we shortly found ourselves in possession of an automatic system with three trunk lines to Lansing and a telephone in every office on the grounds as well as in the residences of those who wished to pay the college a small fee for the privilege.

The Lansing Citizens' exchange was under the management of the Grand Rapids Telephone Company which employed an automatic system and an up-to-date automatic exchange was shortly afterward installed in Lansing. At that time the automatic company did not claim that its system was best for a small exchange, but in the light of the experience we have had, we are satisfied that by all odds the automatic exchange was the best for us.

The college electrician calls up the Lansing exchange every morning over the trunk lines to make sure that they are working satisfactorily, and spends perhaps a half hour in looking over the system; the rest of the day he is free for other duties. This test over the trunk lines is necessary because of line troubles that may have occurred and not because of defective apparatus.

I will say that some of the lines to the residences outside of the campus run through a district where wires are numerous and consequently we have had much trouble with those lines, due to imperfect insulation, crosses, etc., and at times the electrician has had to spend a good deal of time on line work. That condition, however, would exist with any system. All our campus phones are connected by means of lead covered cables in tunnels so that we have no line troubles except those mentioned above.

In my recommendation to the Board I predicted that the automatic system would require less attention than any other system, but I was not prepared for the freedom from trouble which we found in the switch room. This system calls for better line work and really puts telephone work on a higher plane.

L. C. Tomlinson: It is very interesting to note the rapid advances that have been made in the past few years in automatic telephony. The large inartistic telephone, in use a few years ago, has been displaced by the small, neat and compact telephone of the present day.

At the same time the central office equipment has passed through a series of changes. By making the units compact, the central office floor space required per 1000 lines, has been greatly

reduced. The apparatus has been simplified and improved with every change. A few years ago an automatic telephone system was considered so complicated, that many telephone engineers considered it quite impracticable and were unwilling to recommend it to their clients, but the ease with which it has adapted itself to all conditions has won the hearty support of most of the progressive telephone engineers.

By the multi-office arrangement of the automatic system a telephone company may reach out and serve the sparsely settled territory, that if served by the manual system, would cause an annual loss to the operating company. Not only do these subscribers receive the same class and quality of service as subscribers whose lines enter the main office direct, but their rates are generally the same, although they are at a greater distance from the main office.

H. A. Robbins: In 1905 an automatic telephone system was installed in the main office building of the Brooklyn Rapid Transit Company, the system being designed for an ultimate capacity of 1,000 lines, but to date only 110 lines have been put in service. The purpose of this installation was

1. To secure quick communication between departments, and the several offices of the departments.

2. To relieve the general switchboard, in order to obtain better service on outside calls.

The results anticipated from the installation have been very satisfactorily realized, and a large proportion of the inter-office communication is handled over the automatic system tests having shown from 80 to 120 calls per hour over this system.

As to the operation of the system, probably 90 per cent of reported troubles, although few in number, have been in the instruments. The selectors and connectors in the exchange which might be expected to give the most trouble being almost free from trouble of any kind.

While we anticipated some trouble from cross talk due to low insulation in the exchange, the system has been free from this trouble, and the talking qualities have at all times been equal to those of our manual system. The maintenance of the system is in charge of the building electrician, and requires not more than 15 to 30 minutes of his time each day, the maintenance being almost entirely labor costs. While this system, consisting of the straight Strowger type of apparatus, has given very satisfactory results, the improvements which have been brought out in the last few years, especially the Keith primary and secondary line switches, should increase materially the possibilities of the system in large installations. I believe that the combination of the present manual system and the automatic system will be the ultimate solution of the telephone problem in our large cities.

W. Lee Campbell: The point has been made that if the "busy back" should get out of order, it would probably not be noticed, for a considerable length of time in the automatic

system. The method of taking care of an automatic system is somewhat different from that usually pursued in taking care of a manually operated switchboard. I can best illustrate, I think, the method of taking care of an automatic system by referring to the method which the locomotive engineer uses in taking care of his engine. He does not sit on the engine and keep going until something breaks or something that has worked loose comes off and wrecks the train. He goes out at the stations where he stops long enough, and goes over the parts that he knows from experience are liable to work loose, or to get too tight, or to get out of order in some way, and cause trouble, and with an experienced touch here and there he keeps all the mechanism in working order. Any good mechanician having the care of a machine pursues that same policy, and any successfully operated automatic switchboard must be run on that plan. The "trouble" reports that are commonly used for recording trouble with automatic telephone switchboards divide the trouble into two classes--detected troubles and reported troubles. If the switchboard attendant does not put down more detected troubles than reported troubles, it is generally taken for granted by his supervisor that he is not giving very close attention to his duty. An automatic switchboard is provided with supervisory signals for the use of the attendant, but many of the disorders he notices simply by the sound of the machines. As you know, an experienced locomotive engineer can tell by the sound of his engine whether it is running properly or not, and an experienced automatic switchboard man, who is anywhere within hearing of an automatic switchboard, can tell instantly if there is a machine which is not working properly. If he should fail to notice it, there is always a complaint clerk, an information operator, or somebody at the office, to which the subscriber can report his trouble, just as it is sometimes necessary to do with a manual plant. If a subscriber leaves his receiver off the hook, his attention is called to it in the same way that it is in the case of the manual plant; there is a device called a " howler " connected to his line, which sends an alternating circuit of high frequency and considerable voltage through his receiver, that causes it to give forth a tone called a " howl " and calls the subscribers attention to the fact that his receiver is left off the hook.

In regard to trunk lines and private branch exchange switchboards, these are handled in a manner similar to that in use in manual practice. For instance, suppose there is a private branch exchange subscriber who has a half dozen trunk lines, for handling calls to and from his place of business; they are all given the same number, just as in manual practice, and any subscriber desiring that private branch exchange simply calls the number shown in the directory. If the first trunk is busy, he is automatically switched to the second trunk, and so on until he finds an idle trunk. The apparatus does automatically what the operator does on the manual switchboard. Of course, if

all the trunks are busy, the calling party gets the " busy signal " just as he does in manual practice.

In regard to the cost of maintenance, the maintenance labor for the automatic system is undoubtedly higher than for the manual system. The cost of maintenance material, however, for the automatic system is considerably less than for the manual system. I am not prepared to say, offhand, that the following is positively true, but my recollection is that the cost of new cords alone on the manual system will more than pay for the cost of all the maintenance materials on an automatic switchboard of the same size. The additional cost of maintenance labor on the automatic system is considerably more than offset by the elimination of the operators' wages, and the elimination of these wages takes care of the higher charges on the automatic system, due to the greater first cost.

With reference to depreciation, the oldest automatic system that I know of in operation to-day is the one at Fall River, Mass., which was installed in 1901, and has accordingly been in operation about nine years. I had a letter from the manager of that system very recently and he says that it is working better now than it worked nine years ago, and that the switchboards and telephones both show very little wear. So far as its wearing qualities are concerned, he sees no reason why the system should not be good for a number of years to come. Of course, the system is considerably out of date and it may be advisable to replace it, before it wears out, with a system more modern, although no plans are on foot to do so yet.

With regard to the method of reporting fires with the automatic system, nearly every automatic system in operation is arranged so that a subscriber by making one turn of his dial can report a fire to the attendant at the central office. This attendant throws a key and simultaneously rings all of the fire alarm stations, or as many as the authorities desire to have rung, and reports the fire. The method is very similar to that in use in manual practice, with the exception that the calling subscriber has to know the number to call, in order to give the alarm. It is very common in cities where the automatic systems are in use to have fire alarms sent in through the automatic switchboards. It may be that the party on whose premises the fire occurs is sometimes too excited to be able to report it, but I have never heard of such a case.

With reference to pay stations, there are very few pay stations in operation in connection with the automatic system, and in fact there are very few pay stations in operation in any independent telephone system. The pay station with an automatic system is operated in this way: The subscriber removes his receiver from the switch hook and calls the party he wants, in the usual manner. If the party answers he then drops his coin. Until he drops the coin he cannot talk to the called party, but he can hear the called party answer him. As soon as he

drops the coin, his transmitter circuit is closed and he proceeds with the conversation. If he wants "long distance," or "trouble operator" or some one to whom he should have free service, the apparatus is arranged so that it is not necessary for him to drop a coin in order to close the talking circuit.

Frank F. Fowle (by letter): Mr. Campbell's paper gives a very good perspective of the principal features of a full automatic system, up to 100,000 subscribers. This limit meets the conditions at present in all but the largest cities, so that it is fair to draw general comparisons with manual systems.

The general question of manual versus automatic systems is a many-sided, complex subject, to which full justice cannot be done in a brief discussion. It is one of those questions which can never perhaps be settled for all persons under all conditions, and for all time. On the whole, the recognition accorded to automatic systems and service is increasing, and they are coming into greater use.

There are to-day three basic systems of telephone operation; the first and earliest of these was the full manual, the next was the full automatic, and the last the semi-automatic or automanual. A comparison of these systems should embrace all questions relating to service, economics and rates, along somewhat the following lines:

1. Service	Transmission. Reliability. Accuracy. Speed.	
2. Economics	Operating. Expenses.	General. Operation. Maintenance.
	Fixed charges.	Taxes. Insurance. Depreciation. Interest.
3. Rates	Exchange.	Business. Residence. Special.
	Toll.	

The manual system is much the oldest of the three, dating back to the origin of the business. The oldest automatic system in service has been in use about 10 years, only. The automanual system is comparatively recent, and the only installation in the writer's knowledge is at Ashtabula, O.

Full automatic and full manual systems are generally well understood as to their principal features. The auto-manual

system is a compromise between the other two. The subscriber's station equipment and the method of calling the central office are similar to the manual system; after the arrival of the calling signal at the central office the procedure is different. The subscribers' lines do not terminate in front of an operator, but any incoming call is automatically switched to the first idle operator. The operator's equipment consists of a keyboard equipped with numbered plungers or keys much in appearance like the keyboard of an adding machine; there are also lamp signals and selecting keys. There is no multiple of lines before the operator and none of the equipment used in the manual keyboard. The first idle operator receives the calling signal, takes the subscriber's order, sets up on her keyboard the number called for and presses a key which causes that number to be automatically selected. The ringing is automatic and the operator is automatically cut out of the connection, so that full privacy is insured. When the subscribers hang up their receivers, the connection is automatically cleared.

This system avoids the complicated and expensive multiple switchboard, but retains a human agency in its operation. It seems to be especially adapted to the extension of manual systems where a conversion to the full automatic is not desired. A comparison of some of the individual features of these systems will now be taken up.

SERVICE

Transmission. Efficiency of transmission is a matter of electrical design and the selection of equipment. There is fundamentally no reason why the three systems cannot be designed to have equal efficiency in this respect, but both the full automatic and the semi-automatic have an advantage over the full manual system, in avoiding the electrostatic capacity and the resistance of the multiple, including the cable and the jacks. The effect of a large multiple on transmission is an important factor, and the loss occasioned in this way can only be compensated for by selecting more efficient equipment and increasing the size of the talking conductors.

The circuits shown in Figs. 8 and 23 of Mr. Campbell's paper differ somewhat from the common repeating-coil circuit and are probably no more efficient; under some circumstances they may be less efficient; as when ordinary solid-core relay magnets are used for impedances, in place of the more efficient repeating coil or impedance coil, constructed with a properly sub-divided iron core. The effect of such core construction is to increase the apparent resistance and diminish the apparent inductance, due to the energy losses in the core.

Reliability. Full automatic service tends toward greater reliability than manual or semi-automatic service, because it depends on no human agency in its operation; it is equally ready at all times of day or night. On the other hand, it possesses some disadvantage in that it is composed of such complex apparatus, and has such a multiplicity of parts and contacts.

It is conceivable, also, that in some of the most recent automatic systems, which employ line switches and substations, a sudden peak in the traffic load might exceed the capacity of the available lines and switches. Insofar as such a condition might exist, it would tend to create a public sentiment against the service. But any such condition should be only temporary, as one of the traffic problems peculiar to automatic systems is that of eliminating the danger of busy line switches and trunks. Reasonably alert supervision should disclose all such faults.

Automatic systems are of course free from interruptions due to strikes of the operators, such as have occurred with manual systems in Chicago and San Francisco. They are also less likely to suffer interruption from neighboring fires, so close as to make it impossible for operators in a manual system to remain at work; instances have occurred where smoke drove the operators from their positions.

The manner in which the upkeep of a plant is taken care of is, of course, a basic factor in the service which it gives. This is particularly true where there are so many moving parts and contacts. It would be very instructive to have a comparison of these systems on the basis of the number of contacts in a complete connection between any two subscribers in the same exchange territory.

The liability of service interruptions increases in some measure with the complexity and multiplication of contacts. This tendency can be offset in part, at any rate, by proper maintenance methods, and in particular by the adoption of the policy of frequent periodic inspections to detect the approach of troubles and faults before they cause actual interruptions. Particularly in large plants, this policy is almost indispensable to good service.

Accuracy. This is one of the important qualities of good service, but rarely attained in perfect degree in manual systems. In fact, the writer has not, in the course of visiting most of the large cities in the country, found manual service that was above criticism. The human element seems to preclude the possibility of 100 per cent of accuracy in service. Under the general head of inaccuracies we should include the following:

1. Wrong numbers.
2. False busy reports.
3. False don't answer reports.
4. False rings.
5. Disconnects, or cut-offs.

All large telephone companies maintain a force to supervise and test the quality of the service. On account of the expense, it has never been the custom to verify more than a very small percentage of the total traffic; the ordinary practice in service testing or supervising does not cover more than one per cent of the whole traffic, and it is usually but a fraction of that figure. When the tests are sufficiently numerous, however, they furnish some index of the general quality of the service. Some results recently given for Chicago are as follows:

	Per cent
Calls completed without trouble	78.5
Reported " busy "	13.0
Reported " don't-answer "	3.0
Cut-offs, double connections etc	1.0
Wrong numbers, fault of operators	3.0
Wrong number given by subscriber	1.5
	100.0

These figures show that nearly one call out of every four is interfered with for some cause, or more than one in five. About one in eight is held up because of busy lines, and one in twelve is interfered with for other reasons. The " don't answer " reports, amounting to three per cent, undoubtedly include some wrong numbers. The writer finds it safe always to verify a " don't answer " by calling a second time, as in some cases the party called responds on the second call, and usually advises that the first call did not reach him. The writer has also experienced the following service: " don't answer " report on first call, " busy " report on second call, party answers on third call and advises that line was not busy and no previous call or signal had been received.

Incoming wrong number calls are also annoying to the party wrongly called. The writer's telephone number is 6,033 and he has always been annoyed with calls for 6,433; this arises in part from the difficulty of distinguishing 0 from 4, when pronounced O instead of naught. There are many other instances of confusion of vowel sounds. The remedy of course is adequately loud and clear transmission and clear enunciation of numbers. But there is also the element of operator's errors, including the misunderstanding and mis-giving of orders and misplugging in the multiple. The writer has noticed that bad service at individual telephones, particularly in the way of incoming wrong number calls, seems to vary greatly and is no doubt traceable to inefficient operators on the incoming trunk or B positions, at certain hours or on certain days.

Among the prominent causes of poor manual service are overloaded operators, especially in the " busy hour " or peak load period; inexperienced operators; over-loaded order-wires or calling circuits; poor transmission, especially on order wires, which results in misunderstanding of orders and assignments; and lack of adequate traffic supervision and analysis.

The problem of procuring, training and maintaining an efficient force of operators is one of the important and sometimes difficult problems in manual service. In large cities it is necessary to maintain a training school and in consequence there is an ever-present percentage of non-productive labor. The operating force is usually somewhat unstable and the average length of service is not high.

The auto-manual system tends to eliminate many of these difficulties, because the opportunities for error are greatly diminished. The work of the operator is concentrated upon fewer

functions. The limited experience with it thus far, shows that an experienced operator can handle more than double the number of calls per hour than in a full manual system.

The full automatic system eliminates the operators' errors altogether, and in this respect should give superior service. On the other hand, it places an increased burden on the subscribers, due to the manipulation of the calling device. This burden does not appear, however, to be serious, and seems warranted if it eliminates the operators' errors in the manual system.

Both the semi-automatic and the full automatic eliminate the cut-offs due to errors in manual operation, but they tend to increase the cut-offs caused by accidental manipulation of the switch-hook by the subscriber. In these systems one depression of the hook disconnects the line, and if there is no element of time lag in the apparatus, this is likely to be annoying. A slow-acting disconnect feature seems very desirable.

Speed. Speed in operation is directly a factor in operating labor costs of manual and semi-automatic systems. The sacrifice of accuracy for speed, which is sometimes the result in manual systems when high operator loads are over-emphasized, can hardly fail to create a public sentiment of both inaccuracy and unreliability in the service. The semi-automatic system has a large advantage over manual systems in this respect, and the full automatic probably has an advantage over both, all things considered.

Rapid disconnection, especially on trunk circuits, is one of the important advantages of both forms of automatic operation. Slow disconnects reduce the circuit loads in the busy hour and generally slow up the service. The circuit loads in the busy hour are directly of prime importance in determining the investment in the trunking plant, and in toll lines.

It sometimes occurs in manual operation, that the disconnect signals fail, and in consequence a subscribers' line as well as the trunk line is sometimes tied up for considerable periods. It is conceivable of course that this may happen, with automatic operation, but is seems much less likely, owing to the positive character of the disconnect function.

Other Considerations. Coin-in-the-slot telephones and pay stations require manual operation, and in a full automatic system there is no feasible way to handle this class of service, except by introducing manual operation. This objection does not exist in semi-automatic systems.

Toll service cannot, of course, be handled on a full automatic basis. The experiments which Mr. Campbell describes in substituting automatic selection at the "inward" end of toll circuits, in place of manual operation, are very interesting. The increased circuit load in the busy hour thereby made possible, will have a very important bearing on the toll line investment and should result finally in cheaper rates. It should be noted, however, that where double checking is dispensed with, an in-

creased amount of supervision is essential to detect and prevent fraud, either by operators or subscribers. The fact which should be made plain to the operating force is not that supervision is possible, but that it exists without cessation.

One of the objections often advanced by advocates of manual systems against automatic operation has been the seeming difficulty of joining automatic with manual operation in the same plant. This difficulty exists to some degree, but manual operation in toll service will always be necessary and in toll boards designed for operation with automatic local service exclusively the objection seems more imaginary than real. It has not at least proved an insuperable objection in some of the instances where it has been tried.

Operating Expenses and Charges

Operation. The cost of operation, including operating labor, supervision, rent, light, heat, etc., would seem to decrease in the following order: manual, auto-manual, automatic. Labor is the largest item in this account and the saving in labor costs is of basic importance.

Maintenance. The cost of maintenance may vary considerably even in similar plants equally situated. The efficiency of maintenance is directly a factor in the quality of service, and comparisons are therefore difficult to draw. The character of equipment to be maintained in the respective systems is quite unlike. It has been urged against automatic systems that the cost of maintenance would prove excessive, but given well built and properly installed equipment it is not apparent why this should be so. In fact a comparison between automatic and manual systems does not appear to the writer to offer a very decided choice either way.

Fixed Charges. On the general question of fixed charges, the first consideration is the investment. This in a large measure fixes taxes, insurance and interest. Automatic office equipment costs more than manual, but the distribution system less. Approximately 75 per cent of the investment in a manual system is in the outside plant or distribution system. The saving which results from the use of substations, placed at about 75 per cent in residence territory, is almost certain to prove a substantial ultimate economy in favor of automatic operation. There will be further economies in the trunking plant, brought about through higher circuit loads, with automatic operation and secondary line switches.

The insurance risk on a well engineered telephone plant is low, and the rate should not differ materially in any of the systems. If it varies at all it should probably be slightly higher on manual equipment; the steel cords which are now in wide use have sometimes started fires. This, however, has led to the practice of introducing lateral and transverse fire bulkheads in manual boards to reduce the hazard.

The annual charges for a depreciation reserve fund are determined by the investment and the useful life of the plant. More properly it is the cost of reconstruction instead of the investment, labor and materials costing the same. Automatic and auto-manual plants have not been long enough in service to determine their useful life with reasonable accuracy. The oldest automatic plant in service is about 10 years old, but there are few manual plants that are much older, counting from the date of construction or last reconstruction. The effects of obsolescence and inadequacy have been prominent in the depreciation of telephone properties, because of the very rapid expansion of the business and the frequent advances in the art. For the same reasons depreciation will probably continue to be high, in the case of automatic plants at least. However, there is a growing recognition of the necessity of sound engineering, and plants to-day are more intelligently planned and better constructed than they were formerly. The results of this will inevitably diminish the rate of depreciation, as time goes on. The useful physical life of a well engineered plant ought to be very much in excess of 10 years, with the exception perhaps of some rural systems.

Rates

It seems pretty clear that, aside from any unforseen contingencies, a modern automatic plant should be able to offer lower rates than a manual system, and should in consequence produce a greater development. The important advances in the automatic art are comparatively recent however, and rates do not seem to have been materially affected as yet.

The history of telephone rates shows that in the early days there was no scientific basis of rate making, but rates were fixed at what it was thought the traffic would bear. In many instances they were exhorbitantly high, and consequently suppressed development and stimulated competition. The competitive movement placed rates in many instances too low again, because there was no scientific analysis of cost.

To-day, the generally accepted theory, or the theory toward which we are tending as a whole, is the cost-of-service-plus-a-fair-profit. The rates of public utility companies generally are undergoing revision, mainly downward. But this is only partly true of telephone rates; many companies after ten or fifteen years of operation have found it absolutely necessary to raise them in order to earn no more than the legal interest rate. The failure to provide at all for depreciation and the lack of intelligent planning of the original systems and their extensions have been responsible in part for this state of affairs.

It has frequently been stated that the cost of operating a telephone system increases per unit as the system enlarges. This statement has been advanced in support of high rates in some cities. It is of course true that the unit cost of construction is higher in cities than in towns and country districts, but the

greater density of development to some extent compensates for it. The aforementioned statement is somewhat misleading. The facts in the case are that the cost of a manual multiple switchboard increases in faster ratio than the number of lines, and the cost of distribution increases as the average mileage of wire per line increases. The investment in the distribution system exercises the largest single influence on the amount of the fixed charges. The average wire mileage per line increases with the area of the zone which comprises the exchange territory and within which the schedule of local rates applies exclusively to all traffic; it decreases with the density of development within this area. In large exchange areas more than one central office is a necessity, in manual systems, and where there are two or more offices there is necessarily an investment in a trunking plant. As a whole rates are higher in large exchange districts—higher in cities than in small towns. If the exchange district should be increased without limit, the cost of the trunking plant would make the rates prohibitive. Low exchange rates can be obtained by restricting the exchange area, and this principle has been recognized in at least one large city. Traffic between different exchange districts must bear a toll charge.

What effect the introduction of automatic operation will have upon this phase of the rate problem is not yet decided by any actual experience in very large cities, but in general it should result in lower rates, or, with present rates, in larger exchange areas. But as development will be increased by lower exchange rates, it appears to be desirable to reduce the rates rather than increase the size of the exchange district. The full automatic system as described in Mr. Campbell's paper is not worked out for more than 100,000 stations. This limit is already exceeded in the largest cities and further development of automatic equipment is necessary to fit such conditions. The competition between manual, semi-automatic and full automatic systems is certain to have a healthy result upon the telephone art and it is to be hoped that automatic equipment will soon be adapted for use in the largest cities, with ample margin for growth.

Discussion on "Large Electric Hoisting Plants", New York, March 11, 1910

(Subject to final revision for the Transactions.)

Edward J. Cheney: In connection with the torque diagram shown in Fig. 1 of his paper, Mr. Sykes gives a formula for computing the motor horse power. The evident intention of this is to reach the root-mean-square value of the cycle. This formula is not mathematically correct because the mean square of a sloping line is not one-half the sum of the squares of each end. The expression should be,

$$(\mathbf{a})\quad HP = \sqrt{\frac{\frac{HP_1^2+HP_2^2+HP_1HP_2}{3}\times t+\frac{HP_3^2+HP_4^2+HP_3HP_4}{3}\times t_1+\frac{HP_5^2+HP_6^2+HP_5HP_6}{3}\times t_2}{T_1}}$$

which holds good for all cycles, whereas the formula given in the paper is correct only for cycles with horizontal lines, such as Fig. 2, and is considerably in error where the lines have as much slope as in the usual hoisting cycle.

Ordinarily t and t_2 are small compared with t_1, and consequently HP_1 and HP_2 are nearly equal, and HP_5 and HP_6 are nearly equal, and the formula given above may be simplified without introducing any appreciable error, to the expression

$$(\mathbf{b})\quad HP = \sqrt{\frac{HP_a^2\times t+\frac{HP_3^2+HP_4^2+HP_3\,HP_4}{3}\times t_1+HP_b^2\times t_2}{T_1}}\,.$$

where $H\,P_a = \dfrac{H\,P_1+H\,P_2}{2}$ and $H\,P_b = \dfrac{H\,P_5+H\,P_6}{2}$

After having found the correct root-mean-square value it does not follow that this should be the motor rating. As Mr. Sykes points out, the heat is not carried away at the same rate all the time, the reason being that at standstill and at the reduced speeds of acceleration and retardation, the ventilation is less than at full speed. Now a motor rating is ordinarily taken to mean the rating at which the motor will operate continuously at full speed with a given temperature rise, and apparently this is a very convenient basis and worth maintaining. In order to put hoist motors on this basis and make them comparable with other types they should have such a rating that when operated continuously at full speed at that rating they would have the same temperature rise as when operated on the normal hoisting cycle.

The root-mean-square value of the cycle as determined from

the above formula must, therefore, be corrected by such a factor as shall represent the difference between the average dispersion of heat over the cycle and the dispersion of heat at full running speed. This factor depends upon the relative amount of time at reduced speeds, and also upon the relative importance of ventilation and conduction in cooling effect, and so upon motor speed and general design. It will be readily apparent that a high speed motor is more dependent upon ventilation than a slow speed motor, and the compactly built induction motor more than the comparatively open direct current motor.

The designer must, therefore, determine this factor in individual cases, but for a general approximation it may be taken that the cooling during acceleration and retardation is 75 per cent, and during standstill 50 per cent of that at full speed. From expression (**b**), we would then derive the following expression for the correct horse power rating of motor:

$$(\mathbf{c})\ H\,P = \sqrt{\frac{HP_a{}^2 \times t + \frac{HP_3{}^2 + HP_4{}^2 + HP_3\,HP_4}{3} \times t_1 + HP_b{}^2 \times t_2}{.75\,t + t_1 + .75\,t_2 + .5\,t_3}}$$

where t_3 = time at standstill.

As the generator runs at nearly full speed all the time, no such correction need be made in its rating, and instead of being 10 per cent greater than the hoist motor, as stated by Mr. Sykes, it will very frequently be actually less. In a flywheel set, the motor of the set has no peaks to increase its heating, and so we may have the rather amusing case of a motor driving a generator of greater rating, which in turn supplies power to a motor of still greater rating. Apparently in such cases the efficiency has somehow become reversed, but really the ratings are perfectly logical when properly viewed.

In considering the converter equalizer as compared with the Ilgner system, it must be admitted that in the latter, the flywheel set transforms all the power, while in the former, the flywheel set only transforms the fluctuations above the mean. It must, however, be borne in mind that in the Ilgner system, the power is only transformed once, while in the other system, the excess power must be taken through the transformers, converter and equalizer to the flywheel and, later on, taken back again in reverse order to the line. With very peaked cycles, such as we usually have, this means that the converter and equalizer are not so small compared with a motor generator set. The flywheel must store more energy in the converter system, because the rheostatic losses of the induction hoist motor add to the peak. Taking these facts into consideration, and after a careful comparison of the two systems under various conditions, we must take exception to Mr. Sykes' statement that the converter system is the cheapest to install.

As Mr. Sykes points out, the rheostatic losses of the induction hoist motor with the converter system must be balanced against the losses in the slip regulator of the Ilgner system. Here, also a comparison of typical cycles will show the Ilgner system to have the advantage. The real argument in favor of the converter equalizer system seems to be the fact that the hoist is not dependent upon the flywheel set, and even this fails when the generating station is too small to handle the hoist without a balancing system. The converter system also has some advantages where more than one hoist is to be equalized, but where several hoists are operated the diversity factor may be depended upon to smooth out the line load, and a balancing set is hardly necessary.

A paper presented at the 249th meeting of the American Institute of Electrical Engineers, New York, May 17, 1910.

(Subject to final revision for the Transactions.)

METAL FILAMENT LAMPS

BY JOHN W. HOWELL

The first commerical metal-filament lamp was the osmium lamp, the filaments of which were made of osmium. They had a good commercial life at 1.5 watts per c-p., and were used in considerable quantity in Vienna and Berlin where they were made. They were not shipped to distant points, as the filaments were very fragile, and the metal osmium was so valuable that it was desirable to recover all the lamps after they had burned out.

The tantalum lamp appeared on the market in Germany in 1905 and in this country in 1906. The filament is drawn tantalum wire. This wire has a tensile strength greater than steel; it has a very high melting point, about 2800 deg. cent. according to Drs. Waidner and Burgess. It has radiating characteristics which make it an efficient light giving body. These qualities make it an excellent metal for use in filaments and these lamps have good commercial lives at 2 watts per c-p.

The strength and flexibility of the filament prevents breakage in shipment and adapts the lamps for use wherever they are subject to handling or rough usage of any kind. This valuable quality has enabled the use of tantalum lamp to increase rapidly while in direct competition with the tungsten lamp which operates at a much higher efficiency. The physical structure of the tantalum wire changes with use; it loses its smooth uniform surface and becomes rough, offset and brittle. This change takes place more rapidly on alternating current than on direct current. The cause of it is not definitely known.

Tungsten lamps were first placed on the market in this country about the beginning of 1907. They were sold in Europe in September 1906. The development and production of these

lamps since that time has been very rapid, and in 1909 about 10,000,000 lamps were sold in the United States. This great commercial success of the tungsten lamp and the very interesting physical characteristics of the tungsten filament are the reasons for the presentation of this paper.

Tungsten lamps when first introduced were rated at 1.25 watts per c-p. The announcement of this figure created an immediate interest in the lamp; lamp users anticipated a great reduction in their bills for current; current sellers feared this

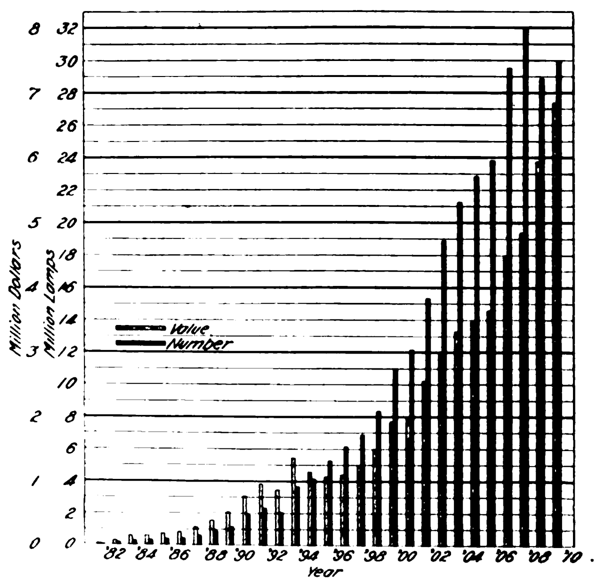


FIG. 1—Showing value and number of incandescent lamps produced annually by one manufacturer since 1881. The values for 1909 cover 11 months

same reduction; lamp engineers and those with scientific interest in lamps were most keenly interested, for to them a lamp with normal life at 1.25 watts per c-p. meant a lamp over 200 times as good as the standard carbon lamp. This figure represented to them the relative quality value of the new lamp when compared with the old standard carbon lamp.

Those who have used tungsten lamps with the object of reducing their bills have done so successfully, for if tungsten lamps are used to replace carbon lamps, candle for candle, a very material economy is effected and also much better lighting secured

due to the much better color of the light and its much greater uniformity throughout the life of the lamp. Other users of the tungsten lamp have utilized the superior efficiency of the lamps to greatly increase the amount of light used while keeping the expense about what it was previously. Generally, however, a course between these two has been followed, the amount of light being materially increased and the cost of lighting also reduced; and experience has demonstrated that at current prices for electricity and lamps, the tunsten lamp will give much more light than will carbon lamps and at the same time reduce the cost of lighting.

The fears of current sellers that their income would be reduced by the introduction of tungsten lamps have not been realized, on the contrary, their income has been increased by the rapid extension of their business into new fields which were opened by the superiority of the new lamps, and by the availability of the larger sizes of lamps which, with carbon filaments, were not successful.

The first tungsten lamps sold in this country were high candle-power, thick filament lamps. There were two reasons for this: the filaments were more easily made than were thinner filaments, and the field of high candle-power lamps had been very imperfectly filled by carbon lamps. These early lamps consumed 100 watts and gave 80 candle-power; they gave us what we did no have before, good incandescent lamps of high candle-power, and they extended the use of incandescent lamps into an unoccupied field. Since that time both higher and lower candle-power lamps have been developed and the adaptability of tungsten to the making of all sizes of filaments has been fully demonstrated. Lamps are now on the market using currents as low as 0.15 ampere and as high as 10 amperes in a single filament.

Tungsten has been a boon to the pocket battery flash light business, in which lamps are now used consuming only 0.4 of a watt. Lamps using 500 watts and giving 400 c-p. are used in large numbers and some 1000-c-p. lamps have been made.

Lamps of the 220-volt class are also made. They require filaments twice the length of those required in 110 volt lamps, and they are therefore more liable to breakage, and are shorter lived at the same efficiency, than are the lamps of standard voltage.

Street series lamps taking from $3\frac{1}{2}$ to 10 amperes and from

6 to 20 volts have short thick filaments and are very long-lived and satisfactory lamps.

Tungsten is one of the heaviest metals known, having a specific gravity of about 20. Its melting point is over 3000 deg. cent. according to Drs. Waidner and Burgess, which is higher than that of any other known metal. Its radiation characteristics are very favorable for its use as a light-giving source, for it possesses the quality called selective radiation, a relative term which implies that the proportion of its total radiations which are in the visible spectrum is greater than that of other substances which are considered normal.

The superior efficiency of tungsten lamps is due to these phy-

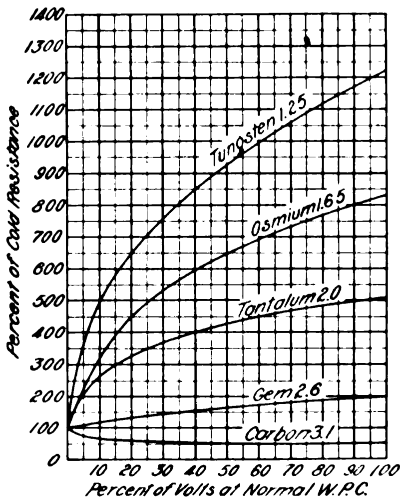


FIG. 2

sical characteristics of the metal tungsten; namely, its ability to remain stable at a very high temperature, and its ability when at this high temperature to emit more than the normal proportion of its radiations in the visible spectrum.

Tungsten has other interesting characteristics; while its melting point is very high it oxidizes at a very low temperature—(about 300 deg. cent.). It also softens at a very low temperature, and filaments which are easily broken when cold can be bent permanently into any desired shape at a temperature below the oxidizing point. This characteristic is taken advantage of in making many filaments of special form, especially in making low voltage lamps; many filaments of spiral or helical form are

made by winding straight pieces of filament on hot mandrels. Similar forms of filaments when made of carbon must be made in the desired form before carbonization.

The change of resistance with voltage in a tungsten filament is very interesting, especially when compared with a carbon filament. The specific resistance cold of carbon is 800 times that of tungsten and at normal working temperature it is 33 times that of tungsten.

The low specific resistance of tungsten is a disadvantage in making high voltage lamps, making it necessary to use very long thin filaments for these lamps. The length of filaments for 120-volt lamps ranges from 450 mm. for 20-watt lamps to

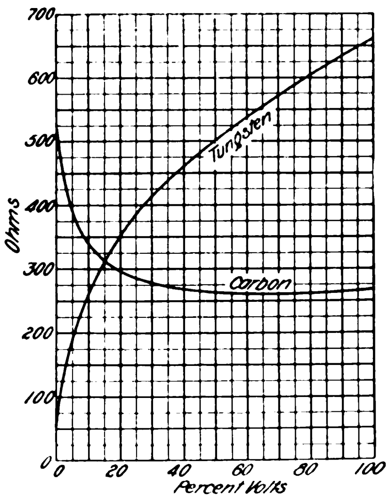


Fig. 3

1400 mm. for 500-watt lamps. The disposal of such long filaments within the proper sizes of bulbs has necessitated a great advance in the art and science of lamp making. This advance has been made, and lamps of standard voltage are now made ranging from 20 watts and 16 c-p. to 500 watts and 400 c-p., all of which are well designed and of good quality.

For low-voltage lamps this low specific resistance is an advantage, giving more desirable dimensions of filaments for such lamps. This advantage has caused a considerable increase in the use of low-voltage lamps for many purposes in connection with storage batteries, and has led to the introduction of a residence lighting systems using 27 and 60 volt lamps, which are

used with compensators or transformers on ordinary alternating-current circuits. These lamps have shorter and thicker filaments than lamps of standard voltage and the same candle-power. If filaments of the same diameter are used the filament will be one-quarter as long and give one-quarter the candle-power of the 100-volt lamps; thus, with the same filaments which are used in 20-watt, 100-volt lamps, lamps of 25 volts using 5 watts and giving 4 c-p. are made. These low candle-power lamps are very desirable in residence lighting in places requiring only a little light, and in chandeliers and clusters in which ornamentation is required as well as illumination.

If we compare lamps of equal candle-power, the 25-volt lamps will have filaments 0.4 as long and 2.5 times the diameter of

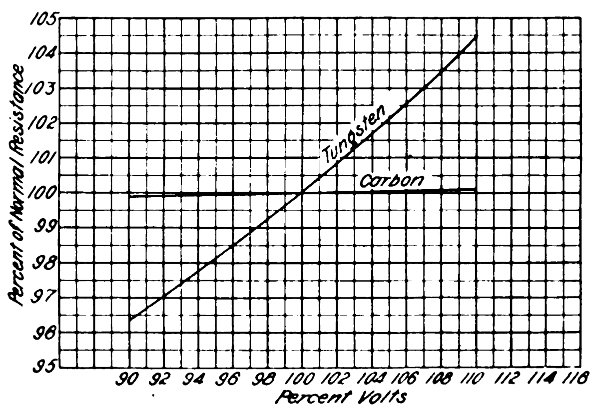


FIG. 4

those in 100-volt lamps, and the 25-volt lamps will be less easily broken by rough handling and will give longer life at the same efficiency. This longer life is due to the greater diameter and shorter length of the filament, for a thicker filament is less affected by minute imperfections, and a shorter filament has proportionately less chance of containing such imperfections.

Many lamps are now used in automobile headlights. These lamps have short thick filaments, which are not broken by the vibrations or jars to which they are subjected, and are very convenient sources of light. Ten-candle-power lamps in good parabolic reflectors give a very satisfactory light. These require 12 watts each, and ordinary storage batteries are well adapted for their use.

These resistance characteristics affect the rates of change of the candle-powers, efficiencies and lives of these lamps with changes of voltage, and curves are given showing the relative resistance changes of carbon and tungsten for a small range of voltage above and below the normal operating voltages of the lamps.

These curves show that in a tungsten filament an increase in voltage is met and partly counteracted by an increase in resistance, while in a carbon filament the resistance remains practically constant; consequently any increase in voltage produces less increase in watts, less increase in candle-power and less decrease in life in a tungsten filament than in a carbon filament.

It will be observed that an increase of 3.7 per cent in voltage will halve the life of a carbon lamp while it requires an increase of 5.2 per cent to halve the life of a tungsten lamp

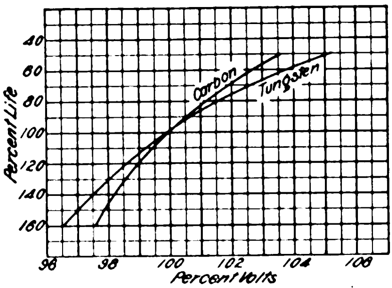


FIG. 5

The cold resistance of a tungsten filament is only one-twelfth the resistance at normal operating temperature, consequently when first connected to the circuit the current is for an instant much greater than the normal current. This excessive current is of sufficient duration to cause an instantaneous rise in candle-power, which is higher than the normal candle-power; this effect has been called overshooting.

Tungsten filaments as generally made today consist of an agglomeration of fine particles of metallic tungsten. These particles are sintered or welded together by raising the filaments to a very high temperature in a reducing atmosphere. This sintering is made as complete as the limitation of our knowledge of the art permits, and while great improvements have been made in this matter the best filaments are still more fragile than are carbon filaments. This fragility has been the greatest

obstacle met with in the introduction of tungsten lamps, and in the beginning, when filaments were much more fragile than they are to-day, and when people had not learned the degree of care necessary in handling them, and when prices were very high, this weakness prevented many people from using the lamps. Now, filaments are much stronger, people have learned to handle the lamps carefully and prices are lower, so that the sales of tungsten lamps are increasing rapidly.

Flexible mountings for the interior structure of the lamps, which protect the filaments to a considerable degree, have been designed, and many lamps for railway car lighting and other special service are now being made, which have these flexible supports, to prevent breakage of the filaments in shipping and also in use.

The latest development which has been publicly announced is the drawn tungsten wire filament. This drawn wire has very great tensile strength, greater than steel, and can be drawn to any desired size. These filaments are very strong and are not injured by rough handling. In life and efficiency they are fully equal to pressed filaments.

Tungsten filaments when burning are quite soft and plastic and must be supported at points sufficiently near together to prevent the filaments sagging and touching each other or the glass. Spring supports are used in many lamps designed to prevent sagging and they do in fact keep the filaments nearly straight under all circumstances. These supports prevent the filaments being attracted over against the glass and being broken by static electricity which is a frequent cause of trouble with carbon lamps.

The variation of light from a filament due to the variation in current caused by the successive impulses of an alternating current depends upon the heat capacity of the filament, the heat radiating characteristic and the resistance characteristic. Tungsten has a specific gravity, about 10 times that of carbon and a specific heat one-fifth as great, so the heat capacity of a tungsten filament is about twice that of a carbon filament of the same dimensions. The heat radiating characteristic of tungsten is better than that of carbon because at a given temperature it radiates heat less rapidly than does carbon.

The resistance characteristic of tungsten is also more favorable than that of carbon for the retention of energy and heat as the current wave recedes. All these physical characteristics of

tungsten are therefore better than those of carbon in respect to the retention of heat, and they all tend to make the flicker of tungsten lamps less than of carbon lamps of the same size filament.

The actual diameters of tungsten filaments, however, are much smaller than those of carbon filaments of the same candle-power lamps, and this more than offsets the advantages of the other characteristics, for the flickering of tungsten lamps is greater than that of carbon lamps of the same candle power, while it is much less for lamps with the same size filaments.

The flicker of a 25-watt tungsten lamp on a 60-cycle circuit may be observed by standing with your back to the lamp and moving a pencil rapidly back and forth, but I have been unable to observe this flicker by ordinary observation.

The flicker of a 40-watt tungsten lamp on a 60-cycle circuit is scarcely perceptible on a moving pencil.

Lamp Testing

Lamp testing is an absolutely necessary adjunct to lamp making, and it is also a very necessary adjunct to proper lamp using. In order to determine the relative quality or value of different lamps, it is necessary to compare their lives at the same watts per candle-power or else to know the law of the relation of lives of lamps to their watts per candle-power, and I know of many cases in which inventors and investors have deceived themselves by judging the value of lamps when they did not know the rate of variation of life with efficiency, or the value of the time element in a test on a lamp.

From the results of experiments made over twenty years ago it was deduced that the lives of lamps at different candle-powers varied inversely as the 3.65 power of the candle-power. These experiments were made on lamps with untreated bamboo filaments. When treated carbon filaments came into use a great many experiments were made to determine whether or not this same exponent was true for them. The conclusion was that the same exponent should be used for both types.

Again when metal filament lamps became established the same question arose, and now comparisons have been made upon large numbers of lamps at different candle powers, each comparison being made between lamps of the same type, and the result of these comparisons indicates that the same exponent which is used for carbon filament lamps is also the proper one for lamps

with metal filaments. In order to determine such a law it is necessary to make comparative tests upon a great many lamps, for it is impossible to get lamps so perfect that they each show the proper relative life to all the others. Averages must be used, and the law must be an empirical one. The exponent we have determined may simply indicate the relation between lamps of the usual degree of imperfection, but its persistence for so many years is remarkable, and we believe that it applies to all types and sizes of lamps which are well designed and well made.

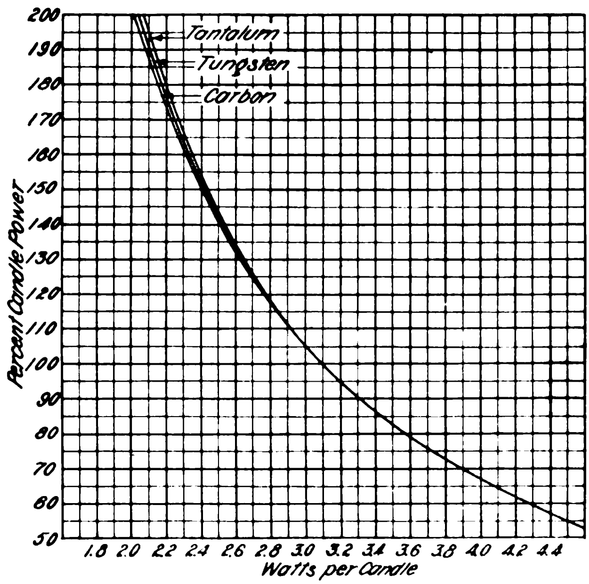


FIG. 6

From this relation between life and candle-power we can determine the relation between life and voltage, current, watts, or watts per candle-power. The relation between life and voltage or current depends upon the resistance characteristic of the filament and as different types of lamps have very different resistance characteristics, a different relation will be found for each type, and these relations are very little used.

The relation between life and watts or watts per candle-power is very nearly the same for all different types of lamps, because the relation of candle-power and watts per candle-power is nearly the same for all types. But as it is not quite the same it is customary to refer all life relations to the candle-power curve o

the lamp for we consider this relation the same for all kinds of lamps.

LIFE FACTORS OR PER CENT LIFE OF TUNGSTEN LAMPS AT VARIOUS WATTS PER C. P.

Watts per c.p.	0	1	2	3	4	5	6	7	8	9
0.1	—	—	—	—	—	—	—	—	—	—
0.2	—	—	—	—	—	—	—	—	—	—
0.3	—	—	—	—	—	—	—	—	—	—
0.4	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.15
0.5	0.17	0.20	0.23	0.26	0.29	0.33	0.37	0:42	0.48	0.54
0.6	0.61	0.70	0.80	0.91	1.03	1.15	1.28	1.42	1.57	1.74
0.7	1.93	2.13	2.34	2.56	2.79	3.03	3.30	3.60	3.93	4.30
0.8	4.71	5.15	5.62	6.13	6.69	7.31	8.00	8.77	9.63	10.60
0.9	11.70	12.60	13.65	14.65	15.70	16.75	17.85	19.00	20.20	21.50
1.0	23.00	24.50	26.10	27.80	29.50	31.30	33.20	35.20	37.30	39.50
1.1	41.80	44.70	47.65	50.65	53.75	57.00	60.75	64.60	68.55	72.60
1.2	76.80	80.85	85.20	89.85	94.80	100.00	106.50	113.30	120.40	127.80
1.3	135.60	143.00	151.00	159.00	167.00	175.00	184.00	193.00	202.00	211.00
1.4	221.00	231.00	242.00	253.00	264.00	275.00	286.00	298.00	310.00	322.00
1.5	335.00	349.00	363.00	377.00	392.00	407.00	423.00	440.00	458.00	477.00
1.6	496.00	512.00	531.00	552.00	572.00	595.00	617.00	640.00	666.00	690.00
1.7	717.00	746.00	776.00	807.00	839.00	872.00	905.00	938.00	972.00	1007.0
1.8	1043.00	1081.00	1120.00	1160.00	1201.00	1243.00	1285.00	1327.00	1370.00	1413.00
1.9	1457.00	1510.00	1564.00	1619.00	1675.00	1734.00	1797 00	1864.00	1935.00	2010.00
2.0	2089.00	—	—	—	—	—	—	—	—	—

This table is made for use with metal filament lamps. It shows their lives between 0.4 and 2 watts per c-p. in percentage of their life at 1.25 watts per c-p. This table is very useful in interpreting life tests made at various watts per candle-power.

Metal-filament lamps last so long when tested as 1.25 watts per c-p. which is their normal rating, that it is customary to test them at higher efficiencies. Tests at one watt per c-p. are usually made; many tests at 0.75 watt per c-p. are made when quick results are desired, and daily factory tests, outside the life-test department, at double voltage, are very valuable when properly interpreted.

All tests comparing different types of lamps should be made on the basis of their spherical candle-powers, for the ratios between the spherical and horizontal candle-powers of lamps is sufficiently different to introduce very considerable errors if

they are compared on the basis of their horizontal candle-powers, as is quite generally done.

Tungsten lamps of the ordinary 110-volt type have a spherical candle-power which is 0.785 of their horizontal candle-power, and when taking 1.25 watts per c-p. on the basis of their horizontal candle-power are taking 1.59 watts per c-p. on the basis of their spherical candle-power.

Many lamps for 63 volts are used for train lighting, and these lamps have a spherical candle-power which is 83 per cent of their horizontal candle-power. When taking 1.25 watts per c-p. on the usual horizontal rating they are taking 1.5 watts per c-p. on basis of their spherical candle-power. If life tested at

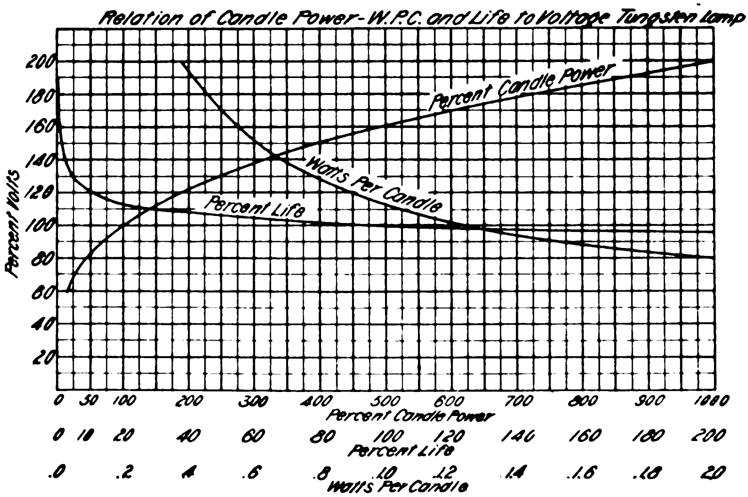


FIG. 7.

1.25 watts per c-p. horizontal, these lamps should have 335/477 or 0.7 as long life as a lamp of the 110-volt class having the same diameter filaments and also tested at 1.25 watts per c-p.

These lamps are tested at 1.25 watts per c-p. horizontal, and appear inferior to similar lamps of standard voltage, thereby suffering from an improper comparison.

The relation between horizontal and spherical candle-power depends upon the arrangement of the filaments in the bulb. As tungsten lamps generally have a number of simple loop filaments arranged in series, the relation will depend upon the height and spread of the filaments; the number of filaments in a bulb does not affect it.

A paper presented at the 249th meeting of the American Institute of Electrical Engineers, New York, May 17, 1910.

SOME DEVELOPMENTS IN MODERN LIGHTING SYSTEMS

BY C. W. STONE

The modern, so-called lighting station is in reality not exclusively a lighting system but a composite system, and is rapidly changing in character.

It is not the intention to discuss in detail any of the modern developments, but simply to mention them with the hope that a full discussion will ensue.

The central station companies, not only in the large cities, but in the smaller cities as well, are rapidly recognizing the value of what is rightly termed the "diversity load factor," and are, therefore, building up the power load by making contracts with railway companies, manufacturing concerns, etc., and, in consequence, are producing cheaper power. The lighting system is thus benefited by this reduction in the cost of producing power and greater assurance is obtained of continuity of service, and better regulation is secured.

With reciprocating steam engines, the largest size units in commercial service are approximately of 5,000 kw. capacity, and it seems probable that no units of larger capacity will ever be built. It is realized that practically the highest economy obtainable from reciprocating engines has been reached, except by greatly increasing the cost and adding complications. The principal attention of engineers building these stations consequently has been concentrated upon the simplification of the power house, the reduction of labor expenses, and the reduction of distributing expenses.

The advent of the steam turbine, however, opened up a new field, and the central station designers immediately saw possibilities for reduction in operating cost, which would make it

possible to furnish considerable power at greatly reduced figures, and thus raising the load factor and tending to reduce the entire cost of power. It is probable that the growth in the future will be towards the concentration of all the power required for a community on one large system, the current for which may be all generated in one power house, or in a group of power houses. This power can then be distributed through the medium of a distributing company to all the manufacturing plants, hotels, apartment houses, railways and residences. Such a power house, or power system, at once becomes a very valuable asset to any community, and would result in lower cost of both power and light to all classes of consumers, and greater assurance of continuity of service would be realized.

I think this is well illustrated by comparing the reports of existing systems where one system has a very much larger connected load than the other system and yet the second system shows a greater number of kilowatt-hours generated, and in consequence, its gross income will be greater. The system with the smaller connected load and yet largest total kilowatt-hours generated will in consequence earn a larger dividend.

With the old reciprocating steam engine, little could be gained by using high vacua and high degrees of superheat; that is, although by increasing the vacuum and increasing the superheat economy would be realized with the engine, the rate of increase in economy would not be great enough to warrant the great increase in cost.

With the steam turbine, however, full advantage can be obtained by increasing the vacuum and the superheat. This immediately started investigations into the betterment of condensing facilities and of superheaters, so that practically all new lighting systems now make use of very much higher degrees of superheat and of vacua than were ever considered feasible for stations using reciprocating engines.

In order to produce better vacua, the auxiliaries must be of a superior type, and in the modern station it is usual to concentrate a great deal of auxiliary apparatus, such as circulating pumps, air pumps, and similar apparatus, on one or more single engine units.

The exciters in a station containing small reciprocating engine-driven units are of considerable size, due to the fact that the slow speed engine-driven units require so much excitation. The steam turbine requires very much less excitation in proportion

to its capacity, and in consequence, the exciters are smaller. For instance, if we had a station employing ten 5000-kw. engine-driven units, operating at 75 rev. per min., the exciter capacity would be about 600 kw. On the other hand, if we had a steam turbine station employing four 14,000-kw. units, or a total capacity somewhat in excess of the engine-driven station, the excitation required would be 250 kw.

In such a system, even if the exciters were steam-driven, there would not be sufficient steam to heat the feed water properly, and although some gain would be realized by using less economical steam-driven auxiliaries, more would be realized by taking steam after it had done some useful work in the high pressure stages of the turbine. For heating the feed water, it seems probable that the most economical method of operating such a station would be to drive all of the auxiliary apparatus electrically, and heat the feed water by means of steam from the lower stages of the turbine. This has been done in part in the past, but the energy for driving the auxiliary apparatus has been taken from the main system, and in consequence a disturbance to the main system has in some cases affected the auxiliary apparatus and caused a shut down. If, however, in addition to the main generating apparatus, an auxiliary plant is installed, consisting of engine or turbine-driven units which are not connected to the main system, and all the auxiliaries are electrically driven from this auxiliary plant, any disturbance on the main system would not affect the auxiliary apparatus. The engines driving the auxiliary generators would be non-condensing and the steam would be taken to the feed water heaters, and the steam would also be taken from the second or third stage of the main turbine units for still further increasing the temperature of the feed water. This should result also in reduction in labor costs and in maintenance expenses.

A tie switch could be installed between the auxiliary system and the main system, so that in case of trouble with the main auxiliary units it would be possible to operate the auxiliary devices from the main system temporarily.

The low-pressure steam turbine is another one of the more modern improvements, which has made it possible for the lighting stations which contain reciprocating engine units, to realize some of the improvements in economy which more modern steam turbine stations have produced. Of course, the installation of a low-pressure turbine in conjunction with a reciprocating

unit is not always possible or advisable, but there are few cases where such an installation will not be profitable. In many cases the low-pressure turbine is considered only a method for increasing economy of the station. I think that this is only one of the uses for low-pressure turbines. It should be looked upon more as a piece of apparatus for increasing the peak capacity of the station, as it can be installed usually for not over $25 or $30 per kw., whereas if a high pressure unit is installed, it is necessary in most cases to enlarge the building, install boilers and similar apparatus, and the labor charges are also increased in proportion to the amount of additional apparatus.

The simplest form of low-pressure turbine of course is that one containing the condenser in the base of the machine, as all other parts are simple and no expensive steam connections are necessary, all of which contribute to the maintenance of high degrees of vacua.

Mr. H. G. Stott discussed this matter thoroughly in a recent paper before the American Society of Mechanical Engineers, and numerous other papers have discussed the details of such an installation.

It seems advisable at this time to call attention to one of the later devices which has been brought out and is now obtainable, for investigating the steam end of the station. I refer to the steam meter (invented by Mr. A. R. Dodge), with which it is possible to keep an accurate record of the steam used with each of the units; and by so doing an accurate check can be obtained on the condition of the apparatus and of the boilers.

One of the problems which always confronts all central station operators is that of protection. It seems to be impossible to so install the circuits, bus bars, feeders, etc., as to prevent short circuits. With small systems a short circuit can readily be handled by existing switching apparatus, but as the systems grow this becomes more serious, and with large modern steam turbines the destructive effect due to a short circuit is almost unlimited. With the old reciprocating engine the short-circuit current might rise instantaneously to 10 or 12 times normal, but with the modern high-speed steam-turbine generator the short-circuit current would probably be at least 50 or 60 times normal, and in such a central station as that of the Commonwealth Edison Co., with all the apparatus operating in parallel, the total energy available instantaneously is probably as great, if not greater, than that of Niagara Falls.

In consequence, it would seem advisable to operate such a system in sections; that is, only a certain number of units in parallel at one time. This method of operating, however, has its disadvantages and is not the most economical method.

It is proposed, therefore, to install a reactance in the circuit of each machine. By this means it is possible to keep the current incident to short circuit within reasonable limits. If such a reactance is used with each machine and the busses are divided into sections—each section with not more than 50,000 kw.—and a reactance placed in circuit between the sections, of such a value as to allow the transference in either direction of the full capacity of one unit, the short-circuit current can be kept down sufficiently low to make it possible to successfully handle it with modern switching devices, and the disturbance to the system will probably be kept down sufficiently so as to make it possible to keep synchronous apparatus in step.

As the individual units become larger, it would seem advisable to design them for low potential, thus making it possible to use deep slots in the armature and a distributed winding, and consequent higher reactance, thus reducing the value of the external reactance which will have to be used. The design of these reactances is a serious problem. They must be built so as to stand enormous strains; they must be thoroughly insulated from ground, and should be built without iron, as the introduction of any iron in the unit would limit its instantaneous effect.

The 20,000-kw. units recently purchased by one of the large operating companies are designed for low voltage, and the reactances, instead of being installed as separate devices, are incorporated in the design of the step-up transformers or compensators. These compensators are designed for low saturation so as to make it possible to realize as much of the effect of the reactance as possible on instantaneous short circuits. The iron in these compensators, of course, is undesirable, but the design is such as to minimize the effect of the iron so that the reactance will be approximately as effective at the time of short circuit as if it were built without iron. The total reactance of each of these units—that is, considering the turbine unit and its compensator as a unit—is about 8 per cent, and it is proposed to operate not more than three of these machines in parallel at one time on one section of the bus. Between the sections of the bus, reactance will be installed as above described.

One of the details in the design of modern stations which is

often overlooked, is that of the proper type of switching devices to be used. Oftentimes the switching equipment is installed for the initial capacity of the station. After the station capacity has increased, the switches are found inadequate for the service and it is necessary to tear out all existing work and install total new switching equipment, which is oftentimes very expensive, but the lack of which is a serious menace to the successful operation of the system.

The capacity of the switch depends entirely upon the amount of station capacity connected in parallel back of the switch. The more modern stations are now being laid out with a view to the future, and plans are made not for the initial capacity but for the ultimate capacity, and the switching equipment is installed accordingly.

Another feature in the operation of central stations which has provoked considerable discussion in the past has been the question of grounded *vs.* ungrounded neutrals. It is generally accepted that the majority of cable troubles start with the breaking down of insulation between one conductor and the lead sheath. With an ungrounded neutral the breaking down of this insulation does not cause a short circuit at first, but simply raises the potential of the other conductors above that of the ground. This may cause the breaking down of insulation on some other part of the system, depending upon its condition, and in case the insulation is sufficiently good on other parts of the system the break-down between one conductor and the lead sheath simply expands and finally includes one of the other conductors of the defective cable, causing a short circuit on the system. The length of time required for this varies of course considerably and may be very short or spread over several minutes. If the neutral of the system is grounded, when one conductor is grounded to the lead sheath it causes a short circuit between that conductor and the neutral, and if a sufficient time elapses between this first break-down and the breaking down of the insulation of one of the other conductors, the feeder switch will open automatically, thus cutting off the defective feeder, and in all probability confine the trouble to the defective feeder.

On a large system, however, particularly those of low frequency and low reactance, such a disturbance may be almost as serious as a short circuit across one of the phases. It would, therefore, seem advisable in large systems to install a resistance in the ground connection so as to limit the current flow at the

time of such a break-down. However, with reactances installed in circuit with each of the generators and between the sections of the busses, this ground resistance would not be required and the neutral could be solidly grounded. It would not be necessary to ground all of the generators, as one ground would be sufficient, although from an operating standpoint it is simpler to ground all machines. No trouble should result from this unless the generators are of widely different designs. In case any troubles result from the transference of current between machines across this neutral connection, the neutrals of similar generators only should be used at the same time. It is hoped that this particular feature will be very thoroughly discussed.

So far, the discussion has been concentrated on the central station end, but it is desired also to refer to a number of new devices which have been developed for the other end of the system, that is, the distributing end. For instance, the practice in regard to substation apparatus has changed greatly during the last few years. Where a direct-current system is used and the frequency of the alternating-current generating system is low—that is, 25 cycles, the commonly used frequency in this country—rotary converters are almost exclusively used for both railway and lighting work. With higher frequencies, such as 50 and 60 cycles, the opinion amongst operating companies is divided; in some cases rotary converters are used and in other cases motor-generator sets. We will not attempt to describe these machines in general, but simply point out some of the features which are of modern development.

It is interesting to note at this time that the average capacity of the machines used in the substations has increased, and where, a few years ago, the largest machines used in substations were 1,000 kw. and more generally of 500 kw. capacity, 2,000, 2,500 and 3,000-kw. machines are becoming quite common.

With the motor-generator sets, the principal changes that have been made have been to develop more fully the use of interpoles on the direct-current generators, the use of higher speeds, and the more general use of the synchronous motor, the latter being used not only to drive the direct current generator, but also as a rotary condenser. The rotary converter, however, has been more radically changed.

This matter was generally discussed at a meeting of the Institute two years ago, when the writer had the privilege of presenting a paper on substation apparatus, so that it will be un-

necessary to go into details in regard to the changes which have been made in the apparatus, except to mention that the split-pole rotary which was at that time generally discussed, has come into general use and is being used for all classes of service all over the country, and the dire failure which was predicted for this type of machine at that time has not been realized.

One of the very successful uses of this machine is for lighting purposes on a railway system, where the fluctuations in voltage of the system are excessive. It is possible to control the direct current voltage automatically by means of an automatic rheostat in the circuit of the regulating pole. Such a machine is used for the lighting of the Grand Central Station of the New York Central railroad. The use of these machines has also become more general for the straightening out of the load curve on such systems as those used by steel mills, the rotary converter being used in conjunction with a storage battery, and under such conditions it operates as a straight converter from alternating current to direct current, or inverted, from direct current to alternating current, the changes being instantaneous.

The rotary converter using the series booster has also been used to a considerable extent.

On account of the increase in power load on lighting systems, the power factors of the systems have become lower and this has caused more attention to be concentrated on the use of rotary condensers.

I will not attempt to discuss in detail what can be realized by the use of such machines, as this subject has been pretty thoroughly discussed in papers before the National Electric Light Association, the Edison Association and in the technical press. I simply want to emphasize the fact that these machines can be used with great economy on almost any lighting system in the country, and wherever they have been installed great economies have resulted.

If the motors which are used to drive direct-current generators are of the synchronous type they can be used as rotary condensers and without much sacrifice in capacity. The relative capacities of a synchronous motor for power and for operation as a rotary condenser, while generally well-known, are often lost sight of and are not taken into consideration in the operation of the machine as much as they should be. For instance, a synchronous motor can be used to deliver 95 per cent of its capacity for mechanical purposes and at the same time can furnish 31 per

cent of its capacity for power-factor correction. The most economical method of operating the machine would be to operate it at 71 per cent of its capacity for power purposes and 71 per cent of its capacity for power factor correction.

Another point which is being recognized more generally by central station operators is that of regulation. Too little attention in the past has been paid to this question. It has been assumed as long as the regulation was reasonably good and no complaints were received from the consumer, that it was good enough. A careful study, however, of the lamp renewals on a system would show in most cases that a considerable expense would be justified for bettering the regulation simply on the score of lamp renewals. A still further saving could be made if good regulation was general instead of being as it is, exceptional, on account of the increase in revenue which could be obtained due to the maintenance of a proper potential. It is possible, by means of automatic regulators, to maintain better voltage regulation on an alternating-current system than can be obtained on a direct-current system. That is, in a direct current system it is not feasible to install substations frequently enough to make it possible to furnish the proper potential to all lights at the same time, although a good approximation is obtained by the use of two sets of busses operated at different potentials, and by the use of feeders of approximately the same drop. In an alternating current system, however, each feeder can be automatically regulated by means of an automatic feeder regulator, and in case the substations are of the type using frequency-changer sets, generator regulators can be used in addition. If the same care is then utilized in the laying out of the feeder system as is usually employed in a direct current system, the best results can be realized. The generator regulator is of a type which is practically instantaneous in its operation and in consequence responds very quickly to sudden changes in load.

There are several types of feeder regulators now on the market, most of which are good, and which will readily earn their cost in a very short time, but oftentimes these regulators are improperly installed; that is, three-phase regulators are used where a single-phase regulator would be preferable. On circuits where the load is more or less rapidly changing, the switch type of regulator seems to be the best type to be used as it will always be quicker in its operation than those of the induction type. In the last few years the design of the induction type regulators has been changed

and their speed of operation has been greatly increased. However, the induction type of regulator has a variable torque. The torque varies with the load on the circuit and also varies with the position of the regulator. In order to get high speed it is usual to make use of a motor with a high speed characteristic; that is, a motor which can reach its normal speed in the minimum of time. If a regulator of this type is designed for operation from one end of its range to the other, in, say, 10 seconds, it will in many cases be good enough for the service required, but of course it can never be as fast as the switch type of regulator as a large proportion of the time required will be used up in getting started. With the switch type of regulator the moving parts are very light and consequently have small inertia and the torque is constant at any point of its range. It is possible, therefore, to use a small motor and magnetic clutches for transmitting the motion to the switch. With both types of regulators a potential relay is required and with the induction regulator a reversing switch is required. With the switch type of regulator the current used in the clutches can be handled by the potential relay direct. This in turn tends to cut down the time required for the operation. The complete range of the regulator can be made very much faster than that of the induction regulator and the speed of operation will be constant throughout the entire range, and it is probable on circuits where the fluctuations on the load are very rapid it will have done its work before the induction regulator has started.

A paper presented at the 250th meeting of the American Institute of Electrical Engineers, New York, May 27, 1910.

(Subject to final revision for the Transactions.)

THE APPLICATION OF PORCELAIN TO STRAIN INSULATORS

BY W. H. KEMPTON

Porcelain possesses some qualities which make it a very good material for line insulators and especially strain insulators. It can be moulded and worked into almost any desired form or size; when made of proper materials and properly burned it has practically no depreciation when exposed to the weather, acid fumes or gases, which sometimes create so much havoc on electric lines. It is hard and dense and has high dielectric strength. It is practically non-absorbent and so is not affected by frost.

The great difficulty in the use of porcelain is its lack of elasticity. It is practically inelastic and has low bending and tensile strength. It has fair shearing strength and good crushing strength. It is these last two properties that make it available for strain insulators.

In order to have definite working data, tests were made to determine the strength of what is known as high voltage stock, in compression, shear and tension. After a number of trials, a pony insulator of the dimensions shown in Fig. 1, and a transposition insulator, Fig. 2, were selected for the compression test. These samples were placed in a Riehle tension and compression machine having a piece of $\frac{3}{8}$-in. fibre above and below the samples to take up irregularities in the porcelain. In the case of the pony insulator, Fig. 1, the break always occurred at the upper groove, and at the middle groove of the transposition insulator, Fig. 2. The average breaking stress for the insulator shown in Fig. 1 was 16,370 lb. per sq. in.; high 21,400 lb., and low 12,200 lb. For the one shown in Fig. 2 the average breaking strength was 12,690 lb. per sq. in.; high 17,400 lb., and low 8,200 lb. In

each case the results are from 10 samples. The shape and proportions of the insulators doubtless account for the different results in the two cases.

For the shearing test, ten pieces like that shown in Fig. 3 were tested in the manner described above. The fracture in each case showed almost pure shear on the line indicated in the sketch. The average shearing stress was 2400 lb. per sq. in.; high, 2,880 lb., low 1,770 lb.

For determining the tensile strength of porcelain, a number of insulators like the one shown in Fig. 9 were selected. They were supported by a free but close fitting ring about the projecting head, and load was applied by means of a steel pin resting against the bottom of the pin hole. Only figures from samples showing a pure tensile break were used in the calculation. The

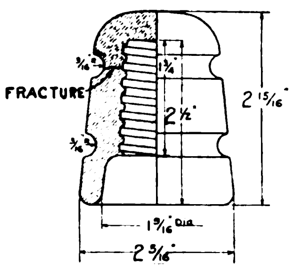


Fig. 1

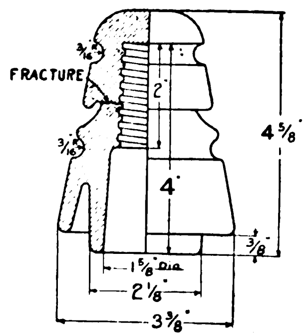


Fig. 2

average of nine samples was 654 lb. per sq. in.; high 897 lb., low 539 lb.

In presenting these figures to the Institute it is realized that if carefully prepared test blocks were used under perfect conditions, much higher results would be obtained, showing the porcelain to better advantage. If the object were an investigation of the porcelain stock such results would be preferable. However, the object of these tests was to secure data for use in insulator design. Inasmuch as perfect conditions cannot be obtained in the practical manufacture of insulators, it was thought that tests from stock insulators under conditions including the imperfections met with in design and manufacture would be more reliable than absolute data obtained from perfect test blocks under ideal conditions.

Some Features in the Design of Porcelain Strain Insulators

As porcelain is strongest in compression, the preferable form of a strain insulator from the standpoint of mechanical strength would be one in which only compression strains existed, and in which sufficient stock was placed under the load to give a proper factor of safety. In practical design this condition is difficult to realize, and the load on most types of insulators gives a combination of compression and shearing stresses.

There are three types of porcelain strain insulators, suitable for high voltage railway work, now on the market and in successful service. The spool type, the loop type, and the compression or barrel type.

The spool and the loop types are the simplest and oldest but

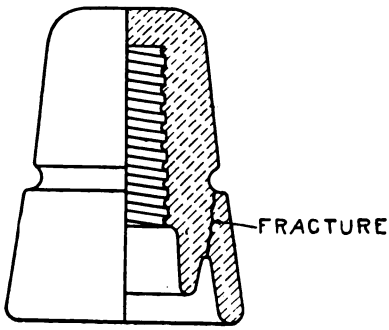


Fig. 3

both are limited in mechanical strength owing to the fact that the load is applied between a cable and pin at right angles, and two cables at right angles, respectively. This throws a comparatively small volume of porcelain in direct compression, the larger part of the load producing bending stresses.

The spool type insulator is further limited mechanically by the possible bending strength of the pin, and electrically, by the amount of surface insulation possible. On account of the inelasticity of the porcelain, if the pin fits the hole in the insulator snugly and the hole is of uniform diameter, the least bending of the pin will throw a bending stress on the insulator and break it. If a metal sleeve be cemented in the pin hole to distribute the load along its length, the expansion of the metal with heat may burst the porcelain. Practical design has settled down to a form of pin hole smallest in diameter under the wire groove and en-

larging toward each end. This allows the pin to bend without pressing on the ends of the pin hole. The problem then becomes one of designing a pin of such length as to allow the desired insulation, and of such diameter as to give the desired bending strength. Of course the walls of the porcelain must be made sufficiently thick to also stand the load.

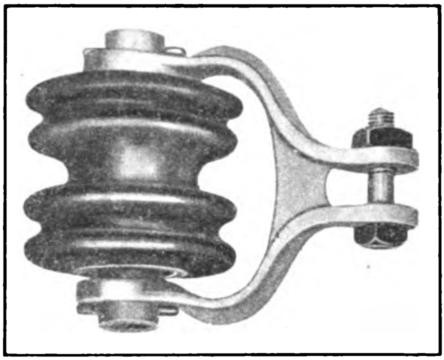


Fig 4

Fig. 4 shows one form of spool strain insulator for 1200-volt service. Fig. 5 shows another form of spool strain insulator with a shorter pin for 6600-volt service. Fig. 6 shows a form of spool strain insulator for higher voltages. These forms of spool strain insulators have an ultimate strength of from 9,000 to 12,000 lb.

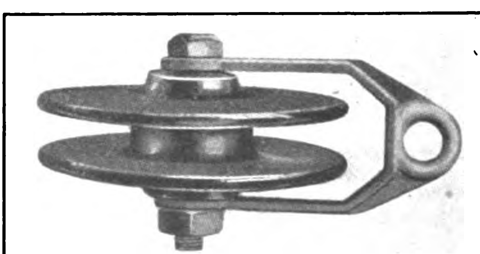


Fig. 5

The ideal porcelain strain insulator would have the load-bearing portion of the porcelain made with two exactly parallel surfaces held between two exactly parallel and absolutely rigid plates. Fig. 7 shows a form of compression insulator which approaches this condition. It consists of a porcelain bushing

with an undercut head portion so that two approximately parallel bearing surfaces are obtained. The head of the bolt passing through the bushing rests on a steel washer bearing on its inner end, and the shoulder of the bushing rests against an inner end of a split cylindrical case, riveted or bolted together over the porcelain head. The irregularities incident to the practical manu-

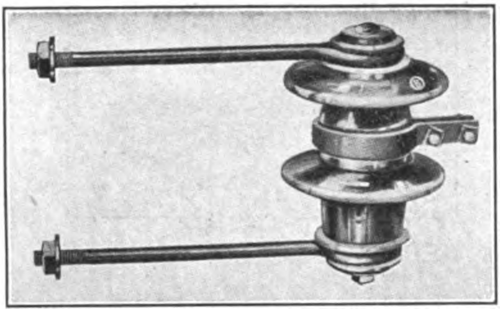


FIG. 6

facture of porcelain are taken care of by placing a lead washer under the steel washer and embedding the portion of the insulator inside the case in neat Portland cement. The bolt head is insulated from the case by means of a porcelain cap cemented over the head of the bolt and the insulator, with a good insulating cement.

The chief requirement in the design of this form of insulator is

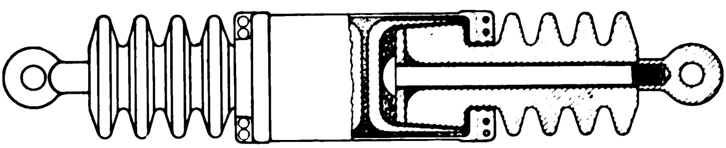


FIG. 7

to make the case of such form, and to reinforce it with ribs, so as to prevent the end bearing surfaces from sagging. If these surfaces sag it throws the load on the outer rim of the porcelain head causing the sides to split off. One sample with a 4-in. diameter head stood a test of 34,000 lb., at which point the bolt broke. On tearing down the insulator a crack in the porcelain was discovered with difficulty. Insulators of about half the

above size, with 2½-in. diameter heads, will stand mechanical tests of from 18,000 to 20,000 lb.

The size mentioned as standing a 34,000-lb. stress—5½-in. diameter of corrugations by 24 in. long—has stood break-down

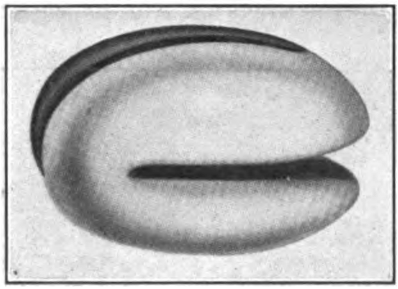


FIG. 8

electrical tests of 80,000 volts, and receives a regular shop test of 50,000 volts for one minute.

It was thought that high mechanical stresses weakened the porcelain stock electrically. To determine this point the follow-

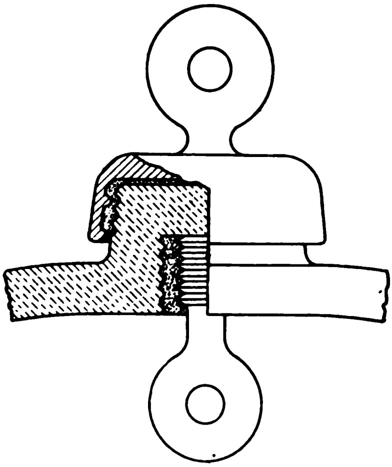


FIG. 9

ing tests were made. Twenty-six insulators like that shown in Fig. 9 were connected in series for simultaneous mechanical and electrical tests. The load was increased by small steps, 70,000 volts being placed on each insulator for 15 seconds at

each step. The test was carried on until three insulators had broken, the broken insulators being replaced each time, and in no case did the porcelain puncture before mechanical breakdown. The failure always resulted in breaking the porcelain off at the lower edge of the cap, so that each porcelain was tested at 70,000 volts at practically its ultimate mechanical strength.

A second test consisted of connecting ten loop strain insulators in series and applying the same test as before. In this case three of the insulators punctured before any of them broke. Inasmuch as this happened at the normal breaking load of the samples and as seven of the ten did not puncture it was thought probable that the high stress in the section of porcelain under the load opened up slight flaws in the stock rather than causing the sound porcelain to puncture below its unstrained puncture voltage.

It will be noted that the above discussion on design is all on

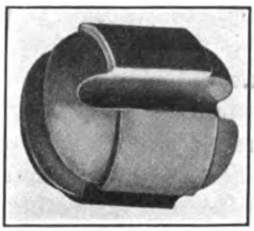


FIG. 10

high-voltage insulators. For low-voltage work what is known as the "goose egg" strain insulator, Fig. 8, has been used for several years and has proved to be quite strong and reliable.

It consists merely of an oval mass of porcelain about 5 in. long by 3 in. thick with wire grooves in opposite ends and at right angles to each other. Practically all of the porcelain helps carry the load directly or indirectly, and a very strong insulator results. Its proportions also make it quite sturdy and proof against rough handling. The ultimate mechanical strength is from 12,000 to 14,500 lb. A smaller size 3¼ in. long, shown in Fig. 10, stands from 9000 to 12000 lb. stress.

These results are from tests made with ½-in. high-grade seven-strand steel cable. If a more flexible cable had been used, higher results would have been obtained, as the hard strands of the cable used tended to cut into the insulator, and being so stiff, did not conform closely to the grooves.

On account of the rough usage they are apt to receive in low-voltage work, however, the moulded form of strain insulator has been more popular. The load being carried directly by metal parts with hard and tough insulation, usually sheet mica, interposed between and surrounded by tough moulded protecting covering, makes a very reliable insulator mechanically, and one that, on low-voltage work, is reliable electrically.

For high-voltage work moulded strain insulators are not so well suited. To stand the higher electrical test the metal parts must be further apart. On account of the resulting greater leverage, to maintain the same mechanical strength, the metal parts must be made much heavier. When large iron parts are embedded in the moulded insulation the expansion and contraction of the metal with heat is apt to crack the covering and admit moisture.

As compared to porcelain all forms of moulded strain insulators whether for high- or low-voltage work possess the element of depreciation due to exposure to the weather that porcelain does not have.

Wood strain insulators for both low- and high-voltage work have become quite popular, chiefly for the reason that long service tests have proved them to be reliable. Owing to the general unreliability of wood, the manufacturer must exercise much care in purchasing and inspecting his stock to maintain its quality. Equal care must be exercised in inspecting the metal caps before and after swaging them to the sticks. Even then, defects are apt to escape the inspector, and it is desirable to test every wood strain insulator mechanically before shipment, to make sure of results.

It will be noted that, although the porcelain strain insulator has certain inherent weaknesses, so has every other kind, and a perfect material for this purpose remains to be discovered.

A paper presented at the 250th meeting of the American Institute of Electrical Engineers, New York, May 27, 1910.

(*Subject to final revision for the Transactions.*)

ELECTRIC RAILWAY CATENARY TROLLEY CONSTRUCTION

BY W. N. SMITH

During the past twenty years overhead trolley construction for electric railways has become such a familiar type of engineering construction, and apparently so settled in practically all its detail, that it is apt to be regarded as commonplace compared with many other features of electric railway equipment engineering. As long as the electric energy for train propulsion was everywhere standardized at 500 to 600 volts direct current, trolley construction practice followed a comparatively well settled and practically uniform line of standards; but since 1904 wide departures have been made from the original forms of railway motors, both as to current and voltage. This advance, made entirely in the interest of economy in transmission, has been accompanied by radical changes in trolley construction which have required the closest engineering attention and have lifted it above the level of the commonplace into which it had generally come to be relegated.

This paper is intended to be a review of current practice in electric railway catenary construction, its purpose being to bring some details of the present state of the art before the Institute in a practical way, to call particular attention to such features of it as may seem to be open for discussion, and to invite expressions of opinion about them; and it is hoped that each interested member will contribute something from his own practical experience so that an interchange of ideas will result which will be helpful to all concerned.

It may be well to state at the outset one cardinal point about

overhead trolley construction, which is often overlooked by those who have given their time chiefly to the fascinating study of electric railway equipment predetermination and especial peculiarities of electric railway motors. I refer to the one thing which makes the electric railway differ from all other forms of electric power transmission and distribution, and that is the fact that the motor derives its power from a moving contact, maintained essentially parallel with the line of travel followed by the motor. The moving element of this contact is carried on the car or moving load, but the fixed element must be as long as the railway line itself, and every inch of it must at all times be in alignment and effectively insulated in order to make the entire railway system effectively useful. No matter how efficient the power station or the motors may be, neither is fully effective unless the contact wire through which they are joined is at practically 100 per cent efficiency. This efficiency must be continuously maintained over long distances and under all conditions of weather and of accidental or intentional interference; and the impossibility of relaying it without interrupting service makes the contact wire the most difficult and uncertain part of the entire system to maintain.

As interurban railways grew in importance, and in the size and speed of their equipment, not only did the necessity for economy in power transmission grow increasingly important, but the problem of collecting trolley current at high speed became more and more serious. The figure 8 and grooved types of trolley wire afforded some relief, but as supports were still 100 ft. or more apart the points of suspension caused slight changes in elevation of the wire, sharp enough to make trouble at high speed. It was not until 1904 that a new step was taken, namely, the elimination of the sag by means of more frequent points of support of the wire, resulting in the development of the so-called catenary type of suspension. This consists simply in supporting the trolley wire practically without sag by hangers of varying length placed every 10 ft., (sometimes 15 ft. or more) the same being supported by a messenger wire hanging in its natural catenary curve directly over the trolley wire. The messenger wire alone is supported on insulators. This type of construction was first successfully carried out on the Indianapolis & Cincinnati Railway, in 1904 from the designs of Mr. B. J. Jones.

This principle of construction has since been adopted in a

number of other installations, with some modification, and has come to be accepted as a practical solution for high speed trolley operation. The original installation was made for 2,200 volts, and installations are now in service with this type of construction using voltages all the way from 600 to 11,000.

The principal features combined in this construction are the flat and smooth alignment of the trolley wire for high speed, the prevention of a trolley wire falling to the ground when broken, which is imperative with high potentials, and the use of a pneumatically-operated sliding bow for making contact, which dispenses with the trolley rope, avoids the necessity of frogs at switches and will stay on the wire at any speed regardless of the swaying of the car.

Although the above mentioned advantages of the sliding bow would seem to be conclusive for high tension trolley operation, it has the drawback of responding more sluggishly to unevenness of the trolley wire than the wheel and pole type of trolley, and this has resulted in a number of cases in the retention of the wheel trolley even in 3,300- and 6,600-volt lines. The writer's observation leads him to believe that the objections to the bow trolley have developed particularly where the catenary construction is defective, due to lack of appreciation of essential difficulties of construction and maintenance, and lack of skill in meeting them. It is easy to allow an amount of slack to go into a catenary trolley wire that will cause sufficient sag in the 10-ft. sections to make kinks at the hanger points, and under such circumstances high-speed operation with a sliding bow trolley is extremely unsatisfactory on account of the resulting sparking and flashing while with a wheel trolley whose rate of vibration is about double that of the pantagraph, such a condition is not so prejudicial to smooth operation.

Types of Construction. Catenary construction is divided into three types as follows:

1. The original and most common is the plain single catenary, with the trolley wire hung directly from the messenger wire.

2. The compound or three-wire single catenary, in which the trolley wire is suspended by clips of uniform length from a tight secondary wire just above it, this secondary wire being supported by hanger rods of varying length from slack messenger wire above it. There are several variations of this type and it permits the use of devices which maintain a uniform tension on the trolley wire through any range of temperature.

3. Double catenary construction, consisting of two messenger wires and one trolley, the latter below and between the other two, the three wires being at the corners of an equilateral triangle and rigidly connected by triangular pipe spreaders varying from 6 in. to 6 ft. on a side according to the sag of the messenger wire. The excessive rigidity of this type has been found to be undesirable in practical operation, and it has been successfully modified on the New Haven railroad by stringing a second trolley wire and fastening it a few inches below the first by clips at points halfway between the original trolley wire hangers. This construction was fully described and illustrated by Mr. W. S. Murray in his Institute paper of December, 1908.

The second of these general types has been extensively developed in Europe, particularly that feature which enables the maintenance of uniform tension on the trolley wire. Conspicuous examples of this type are the single phase lines of the Blankenese-Altona-Hamburg-Ohlsdorf line in Germany, and the Rotterdam-Haag-Scheveningen line in Holland.

Poles and Bridges. No paper on overhead construction can be regarded as complete without giving due consideration to the materials and construction of the poles or towers on which it is carried. In working up this division of the subject, however, there has been accumulated sufficient material of interest to warrant treating it in a separate paper, which the writer hopes to be able to do in the near future.

Where wooden poles are used they should invariably be treated with some preservative, preferably of the creosote type, before being set. The treatment may be either by the vacuum process which involves an expensive plant but thoroughly impregnates the wood; or it may be by the so-called "open-tank" process, in which about eight feet of the butts are treated with hot creosote or similar oil; or, cheapest of all, and yet quite effective, the "brush method" may be used, which simply means painting the pole with hot creosote or similar oil for a distance of about two feet above and two feet below the ground line, applying a second coat after the first coat has had time to soak in. Any engineer can prove to his own and to his client's satisfaction that either of the last two named methods of treatment will pay dividends, as the life of any pole so treated will be lengthened anywhere from 30 to 75 and possibly 100 per cent, according to the treatment used.

Steel poles can be had in three types. The familiar two- or

three-section tubular pole, in either standard or extra heavy pipe; the "tripartite" pole, built up of re-rolled Bessemer steel U-sections with malleable iron collars and spreaders, the steel having an ultimate tensile strength of 100,000 lb. per sq. in.; and the "diamond" pole which consists of two sheet steel

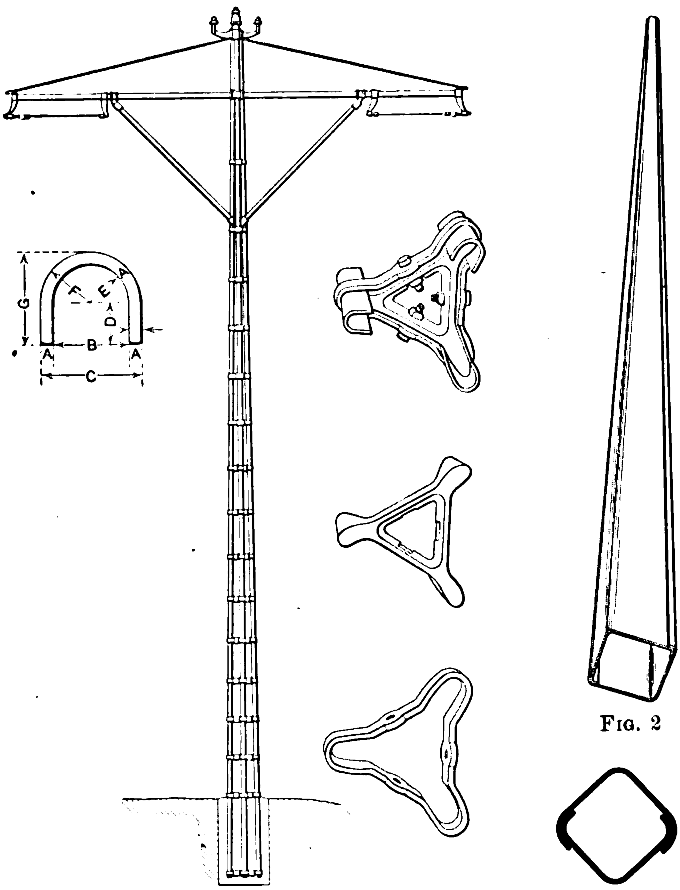


FIG. 2

FIG. 1

FIG. 3

"Tripartite" and "Diamond" steel poles

V-shaped troughs tapered and flanged over the edges, one being driven lengthwise within the other to form, when assembled, a box shaped pole, the extra strength lying in the extra thickness of the overlapping flanges.

The relative merits of these three types of steel poles may be

briefly summed up by saying that the tubular type is the least economical of weight for a given strength; and that while the diamond pole is superior to the tripartite in the matter of weight economy, the tripartite has a great advantage in that the Bessemer steel composing it is almost rust-proof and that every inch of metal surface upon it can be reached with a paint-brush. Its taper can also be varied to suit local conditions.

Reinforced concrete poles have come into use during the past few years, for railway trolley construction. Under favorable conditions they can compete with cedar or chestnut poles as to first cost; they are, roughly speaking, about twice as stiff as a cedar pole and of 30 per cent to 50 per cent greater ultimate strength. Most important of all, they are practically indestructible. A considerable number of them are in use on the lines of the Fort Wayne & Wabash Valley Traction Company.

On account of the load being from two to three times that carried on a single bracket pole in standard direct suspension, it is necessary to use heavier poles for catenary work. If of wood, they should average 25 in. in circumference at the top and should invariably be seasoned and treated with creosote, at least at the butts. The standard setting should be 6 ft. for a 30-ft. pole and 6½ ft. for a 35-ft. pole where the wire is at a high elevation. Over highways, 19 ft. is usually high enough, but in the steam railroad electrification carried out in this country the standard height of trolley wire, except under low bridges, is 22 ft. above the rail. Bracket poles should be set with 14 or 15 in. rake, as they will pull up to about one foot rake after the load has been applied. On steam railroads particular care must be paid to side clearances. Eight feet from center of track to the face of the pole is a minimum, and some roads require more. With an 8-ft. clearance, a bracket 10 ft. in length is sufficient.

Early practice in setting poles or curves, allowed greater offsets than experience has shown to be desirable. One manufacturer's catalogue gives pole spacing based on a maximum variation of 17 inches in the position of the trolley wire with reference to the center of the track. Another one gives seven inches, and a third is somewhere between. It is much safer to prescribe small offsets, and the Denver & Interurban catenary line was laid out not to exceed 3½-in. offsets, as follows:

TABLE OF POLE SPACING ON CURVES

Degree of curvature	Pole spacing feet	Max. offset of trolley wire from center of track, inches
Tangent	120	0
1	120	1.87
2	110	3.37
3	90	3.06
4	80	3.37
5	70	3.06
6	60	2.87
7	50	2.34
8	50	2.64
9	50	2.94
10	50	3.24

On curves, brackets must be so inclined from the horizontal as to be nearly parallel to the position taken by the pantagraph bow, the outer end of which will tilt up considerably, due to the elevation of the outer rail.

For attaching bracket truss rods to pole tops, the three-part pole-collar is preferable to any other means, as a single pattern forging is sufficient not only for the truss rod but for constraining the body of the bracket. This method was devised by the writer for the bracket construction of the Denver & Interurban R.R. in 1907. Insulator pins should be tightly adjustable on the brackets and should be made with a two-part clamp base, which the writer believes preferable to one with a J-bolt base as the J-bolt base will open out when screwed up tightly and has a very limited area of contact on the inside. Insulator pins should be of malleable iron.

Porcelain insulators of the petticoat type, are now universally used, and even over steam railroad tracks they have given no special trouble from gathering soot. The types used on the Erie and the Denver & Interurban lines have been uniformly successful, for three years on the former and two years on the latter railroad. The general form of this insulator is shown in Fig. 4.

Brackets ought also to be stronger than are usually made in direct suspension, particularly if over steam railroads. In the equipment designed by the writer for catenary construction on the Erie Railroad, two truss rods were used per bracket.

Some forms of bracket are made with two horizontal members, one on each side of the pole. To guard against accidents and minimize breakage in case of accident, the writer believes that it is desirable to design the pole attachments to the bracket so that if the trolley and messenger wire break, the bracket and truss rods may be swung around the pole as on a hinge, rather than be broken off or twisted out of shape. This is effected by using pole collars at the butt of the bracket and at the point of attachment of the truss rod, which have the additional advantage of obviating the boring of holes through the pole. Figs. 5 to 10 show several types of brackets used experimentally by the

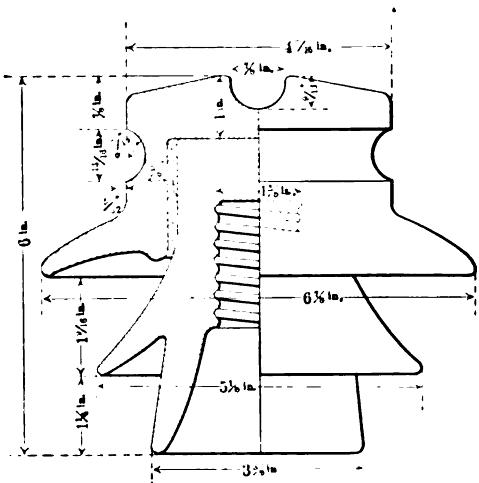


FIG. 4—Porcelain insulator

Connecticut Company. For high voltages, the brackets must be grounded to the rail to prevent a broken insulator from causing the pole to be set on fire.

Catenary Spans and Bridges. The expense of steel bridges for supporting catenary trolley wires over more than two or three adjacent tracks can be greatly reduced by using span wire construction. A number of spans constructed under the writer's supervision at the Rochester terminal of the Erie railroad are illustrated herewith in Fig. 11. In this design the span wires and all supporting fittings are grounded. The trolley wire is supported by suspending from the span wire a stirrup of the same size of tee iron as is used for the bracket. The same type of pin

as well as insulator is used for the span as for the bracket construction on the remainder of the line. The voltage on this installation is 11,000. For lower voltages heavy wooden strain insulators are sometimes cut into the spans without any insula-

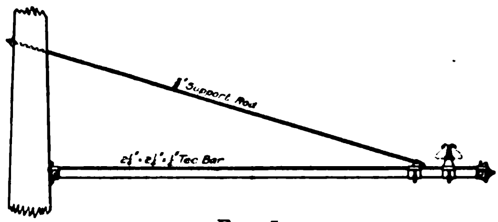


FIG. 5

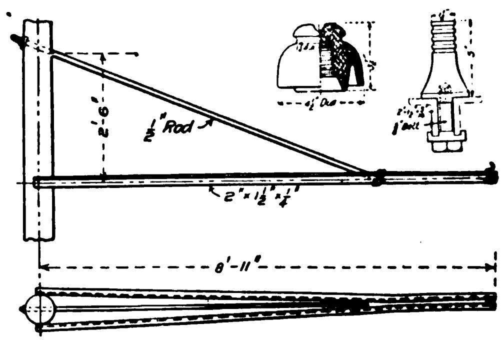


FIG. 6

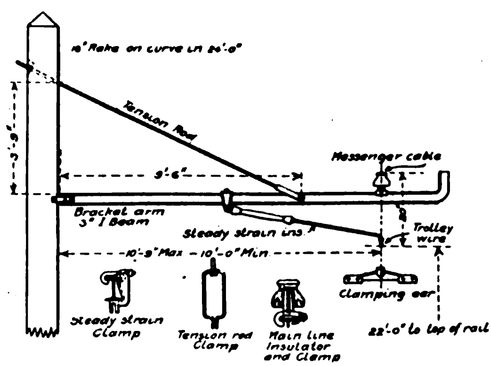


FIG. 7

tion between the span and the messenger wire at the point of attachment, but the advantage of entirely grounded span wires should commend itself so naturally that it does not seem worth while to go to the extra trouble of working various styles of insulators into them.

This form of span is practically in duplicate, though it is intended that the upper should carry the load and the lower act to steady the stirrup sideways. It is hardly necessary to add that steel poles are necessary for catenary span construction of this

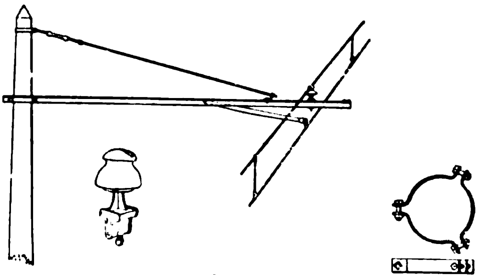


FIG. 8

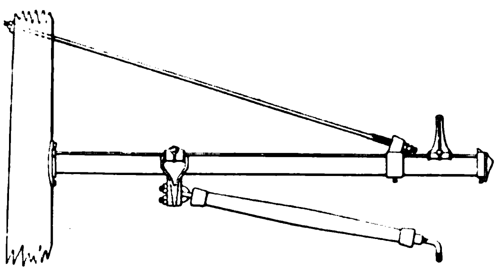


FIG. 9

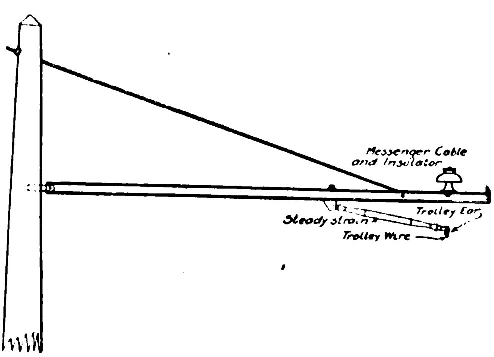


FIG. 10

character, unless there is ample room to substantially guy wooden poles. For this purpose the tripartite pole has been found very satisfactory. The illustration shows seven tracks spanned, being a distance of 96½ ft. across the tracks between poles, and four tracks of the seven electrified.

Some of the latest catenary construction for double track has been supported by a light bridge construction, the most recent example being that of the Rochester, Syracuse & Eastern Railway, recently completed, and illustrated in Fig. 12. This is for 600-volt direct-current construction with bridges 300 ft. apart. It is of the plain single catenary type, without any special adjustment or tension devices. The sag of the cables in a 300 ft. span is about 62 in., the maximum length of hanger being

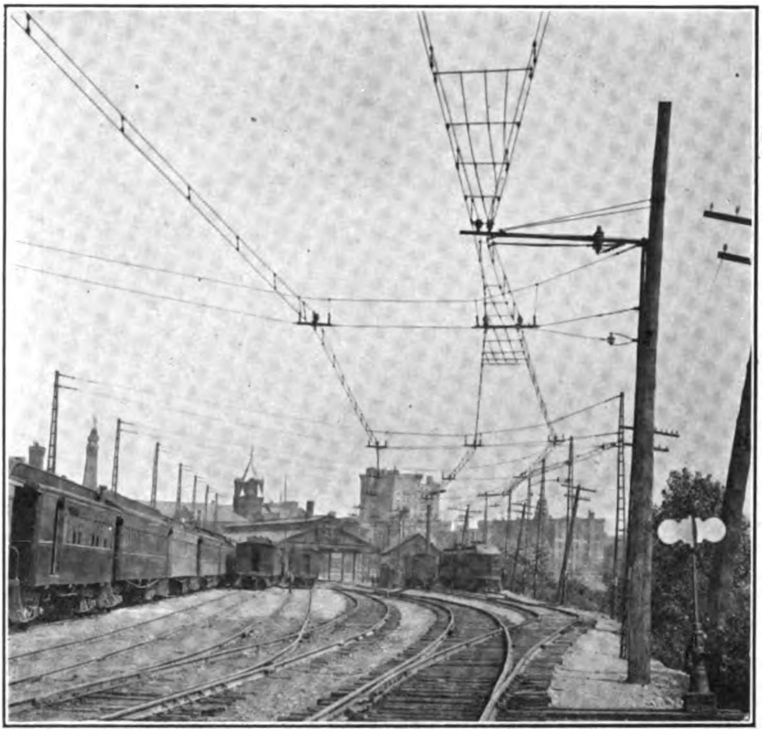


Fig. 11—Overhead construction at Rochester terminal of the Erie railroad

about 67½ in. and the minimum 5¼ in. in length. The form of bridge and foundation is stable and permanent. The side frames of the bridge are 28 ft. between the centers and the spread of each base is 4 ft. The insulators on top of these bridges are of porcelain moulded in a special saddle shape and set on treated timber. There is said to be comparatively little side swaying between bridges. On this particular line the messenger cables are of copper, constituting the feeders and are of 500,000 cir.

mils. The feeder was necessary for power distribution and the cost of the steel messenger wire was saved by this combination.

In the *Electric Railway Journal* for May 22, 1909, were published some figures showing the relative cost of this type of construction compared with the ordinary wooden pole and span wire construction for double track. The fact that the messenger wires were eliminated and the feeders made to do double duty

FIG. 12—Light bridge construction on Rochester, Syracuse & Eastern railway

enabled quite a saving to be made, and the cost of the supporting structures, exclusive of copper conductors, is reported for this particular line as being only $100 per mile of double track more than with wooden pole construction. It is hardly necessary to comment on the greater permanency of steel construction.

The varying costs of steel bridges, poles and wires render it necessary to make very careful estimates for comparison before the engineer commits himself to the adoption of a radically

new type of construction, but there will doubtless be many instances where this type of bridge for a double-track line would prove economical.

The original bridge construction of the New Haven Railroad has been so frequently described and illustrated that it is only necessary to refer to it by name. The newer type of construction now being used by the New Haven Railroad will be referred to later. The writer believes it to be a great improvement over the original.

Messenger and Trolley Wires. By reason of their somewhat intimate relationship, it is desirable to consider messenger and trolley wires together. The original and simplest form of catenary construction utilized a galvanized 7-strand steel cable of high strength steel, with hard-drawn grooved copper trolley wire. The messenger wire has varying sags but a common sag was 10 to 12 in. for a 120-ft. span. The trolley wire which is generally of 3/0 or 4/0 B. & S. gauge, is meant to be perfectly level at average temperature, but owing to the different coefficients of expansion of steel and copper, the trolley wire is relatively tighter at low and slacker at high temperatures than the messenger wire. With the plain type of catenary construction where no take-up devices are employed, the result is that in warm weather the 10-ft. sections between hanger points become slack enough to cause the sliding bows to pound kinks into the wires at the hanger points, and, at any considerable speed, mechanical pounding and electrical flashing are both injurious. The only remedy for this situation aside from providing overlapping breaks, is to pull the wire sufficiently tight so that its strain at maximum temperature will not be less for a 4/0 wire, than 2,000 lb. If the minimum tension at 100 deg. fahr. is to be 2,000 lb., at zero deg. fahr. it will run up to about 5,000 lb., and the elastic limit of the wire is reached at 5,817 lb. As 5,000 lb. is so close to the elastic limit it is to be expected that copper trolley wire pulled tight enough to be effective at maximum temperatures will be likely to get pulled beyond the elastic limit in the course of a season or two, particularly after the outer skin is somewhat worn down by the passage of the moving contact. These considerations may explain much of the trouble that has been experienced with plain catenary construction using hard drawn copper trolley wire. It sometimes happens that when a road is quite crooked, the elasticity of the poles will do something towards maintaining the tension of the trolley wire

at varying temperatures by giving sideways at the curves, but usually the only remedy is to pull out the slack as often as required.

This warm-weather slackness can be obviated where a wire can be pulled sufficiently tight to be at a minimum of 2,000 lb. at a high temperature and 5,000 lb. at low temperature. This can be done with "phono-electric," with steel wire, or copper-clad steel wire. The principal objection to the use of wire other than copper is the decreased conductivity. Phono-electric wire costs more than copper, while steel wire, of course, costs very much less. Both of these wires are so much stiffer than hard

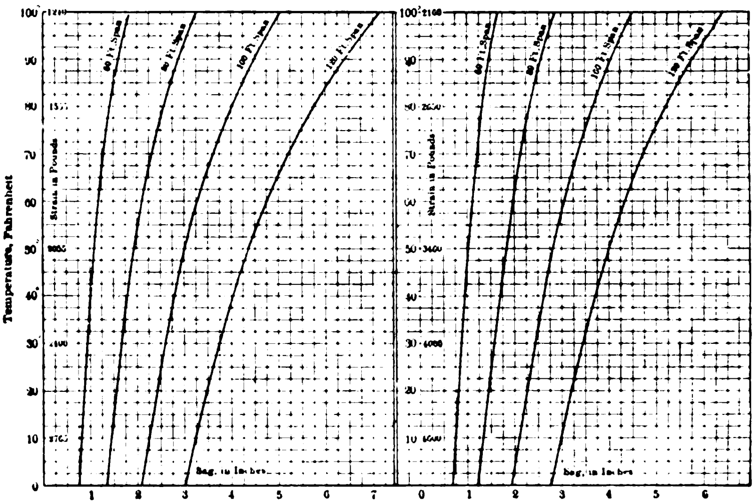


FIG. 13—Curves of messenger and trolley sag

drawn copper that there is a marked tendency to resist kinking. At 11,000 volts the conductivity does not greatly matter when dealing with the usual interurban train weights and distances of transmission.

On the Denver & Interurban Ry. in 1908, phono-electric trolley wire was strung on 45 miles of plain catenary construction, using a dynamometer to register the tension, which was so adjusted that at 100 deg. fahr. there was not to be less than 2000 lb. tension, rising to nearly 5000 lb. at zero deg. fahr. The curves of messenger and trolley sags are shown in Fig. 13*. The

* From a paper on "Catenary Trolley Construction" read before the Am. Soc. C. E., October, 1908, by O. S. Lyford, Jr.

road has been in constant operation for two years and it has not been necessary to pull any slack out of the trolley wire in that time, thus demonstrating the correctness of both the design and the selection of materials.

The use of tension devices for trolley wire as thus far developed, which is chiefly in Europe, does not seem to contemplate tensions of more than 1000 to 1500 lb., and furthermore the clips which hang the trolley wire from the secondary wire directly over it are of a type that will yield vertically, so that the trolley can, as it were, carry a wave along with it as it travels underneath the wire. It is the writer's belief that without the upwardly yielding hangers, it is necessary to maintain a minimum tension of at least 2000 pounds; and that the only excuse for maintaining a lower tension is the ability of the trolley wire to yield at the hangers. Such hangers have not yet been generally adopted for use in this country and the only experiments with them under American conditions of which the writer has knowledge, have not been particularly conclusive. On the New Haven road good results have been effected by a maximum tension of about 5000 lb. on the trolley wire, and without the use of automatic devices for producing uniform tension under all temperatures.

A table is presented herewith showing the characteristics of the four kinds of wire now available for catenary construction, those characteristics being for one size only, No. 4/0 B. & S. gauge, which is that most largely used in catenary construction

PROPERTIES OF TROLLEY WIRE, NO. 4/0 B. & S. GAUGE

	H. D. copper	Phono-electric	Copper clad	Steel
Tensile strength, lb.	8,310	11,330	9,470	12,000
Elastic limit, lb.	5,817	9,640	8,523	9,000
Res. per mile, ohms	0.259	0.575	0.634	2.21
Weight per mile, lb.	3,382	3,382	3,140	2,940
Modulus of elasticity	16,000,000	18,500,000	——	30,000,000
Coeff. of expansion, deg. fahr.	0.00000950	0.00000932	——	0.00000640

An excellent feature of the modified type of compound catenary construction used by the New Haven R.R. is the upward yielding made possible by suspending the contact wire from the old trolley wire at points halfway between the original hanger

points. There is thus available a limited amount of upward yielding, depending somewhat on the temperature. The combination of this yielding effect with the high tension in the contact wire has proved so generally satisfactory that in future extensions of the New Haven system the contact wire is to be similarly suspended.

The clips by which the working conductor is attached to the lower or secondary messenger are fast to both the wires and allow no vertical play other than that due to the yielding of the secondary wire. The European compound catenary however has these hanger clips so designed as to permit the trolley wire

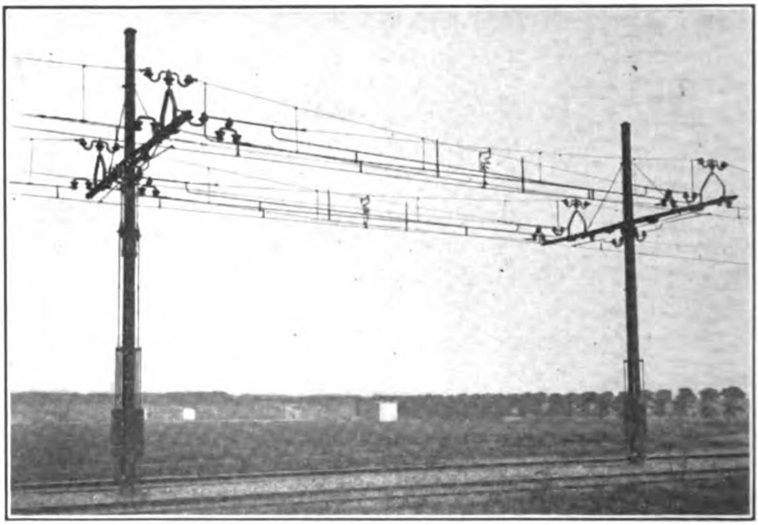


FIG. 14—Catenary construction with strain insulator at each bracket

to yield vertically and as all new European work seems to be designed along these lines the principle under European conditions seems to be successful.

The other principal feature of the compound catenary is the tension device placed at intervals to take up the expansion in the trolley wire due to temperature. This consists of a system of weights operating by chains over pulleys, pulling against the free end of the trolley wire at the end of each section, the consecutive sections overlapping so that the contact bow slides readily to one before leaving the other, there being, however, no electrical connection between the trolley wires of the overlapping sections except during the passage of the bow.

These sections are from 3,000 to 4,000 ft. long and the arrangement serves naturally as a section insulator around which a jumper can be placed if desired. On the line at Rotterdam the builders have cut the messenger wire at every bracket, inserting a strain insulator resting upon the bracket and com-

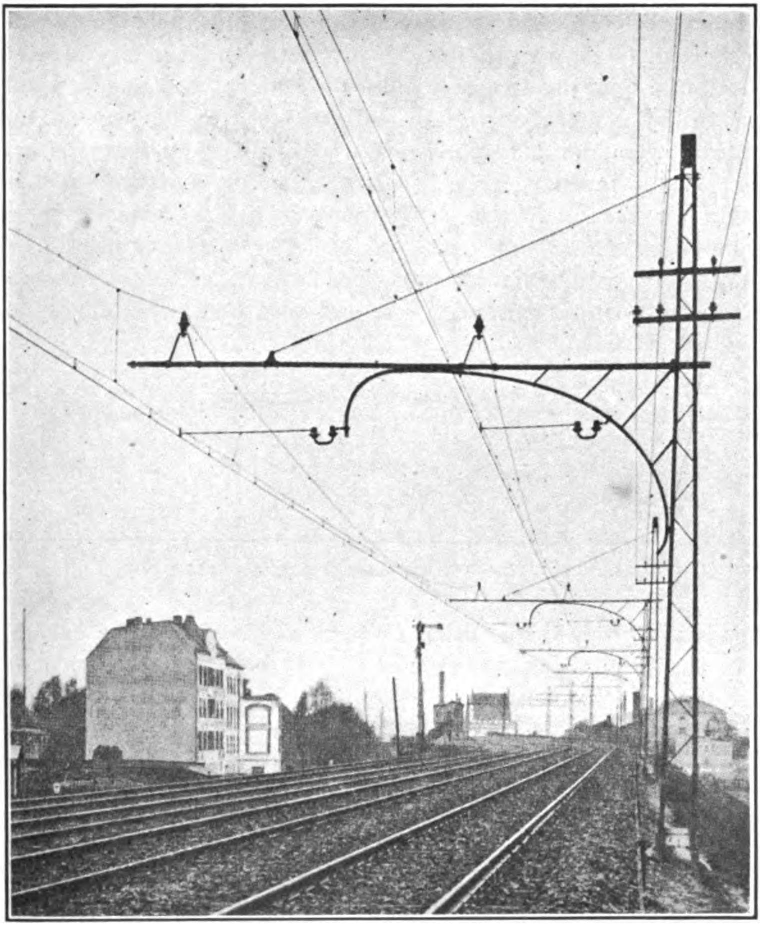


FIG. 15—Catenary construction at Hamburg

posed of three insulators so that there are ordinarily two in series. This construction is shown in Fig. 14. Previous practice, as at Hamburg, (see Fig. 15) and Lancaster, England, adhered to the continuous messenger, but presumably the change was made in the interest of diminishing the effect of changes in temperature of the continuous messenger.

The latest improvement introduced in Europe for eliminating unevenness of operation due to temperature changes is a new design in which there is included an equalizer wire, so-called, which runs above the catenary between brackets without any intermediate hangers, as shown in Fig. 16. Being somewhat shorter and with less slack than the messenger wire proper it tends to lift the catenary at points where it is anchored thereto a short distance away from the brackets, and thereby raises a short bight in the catenary directly under the bracket where the trolley is attached to it, thus lifting the trolley wire at the bracket when temperature is lowered, which would not be the case in the ordinary type of plain catenary construction. In this type of catenary the trolley wire is of hard drawn copper, while the catenary and the equalizer are of silicon bronze, so that all three have similar coefficients of expansion. In several instances a copper messenger wire has been used instead of steel,

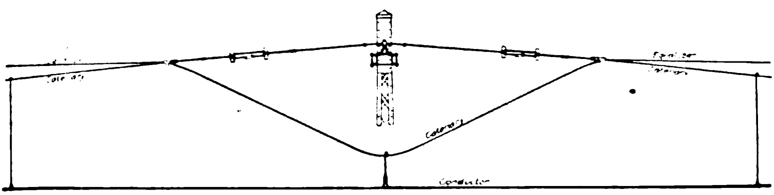


FIG. 16—Catenary construction with equalizer wire

this having been done on lines where low-tension direct current was used, requiring feeder copper. It has the advantage of saving the cost of a steel messenger. The fact that both the trolley and messenger are of the same material will greatly lessen the troubles that have been experienced with a steel messenger and a copper trolley wire.

The excellent service being rendered by steel trolley wire on the New Haven R.R. has suggested to the writer that it might be worth while to propose using a combination of a copper messenger and a steel trolley wire. In this arrangement the trolley wire would expand and contract less than the messenger and it would seem as though it should therefore be more easily kept at required tension. There has not been time to work up the idea in detail but it is submitted for the criticism of those who are interested. It will probably be more suitable for the higher than lower voltages, but as it is no more difficult to insulate catenary trolley construction for 11,000 volts than for 2,200 volts, the

extra cost of insulation due to carrying the higher voltage is insignificant.

Catenary Hangers. There are so many types of catenary hangers that a description of all would be tiresome. Six different companies are each offering several different types of hangers,

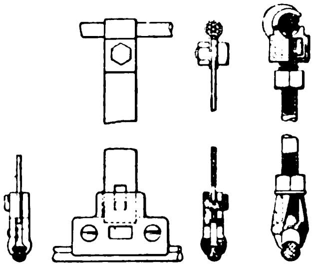


FIG. 17

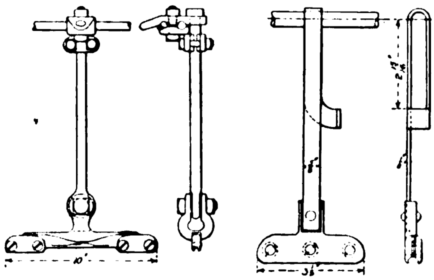


FIG. 18

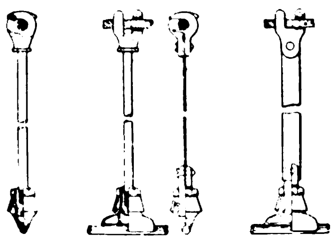


FIG. 19

including both the messenger and the trolley clamps and the rod connecting them. For the plain type of construction there now seems to be a preference for a hanger that has an easy or flexible grip on the messenger wire and a powerful positive grip on the trolley wire, with a joint between clamp and rod, either at the

top or bottom, or sometimes both, to increase the general flexibility. In the earlier work, four or five years ago, messenger and trolley clips were rigidly connected together and even in spite of the lack of experience in design and erection they operated very well in many cases, provided the trolley wire was pulled sufficiently tight.

The Connecticut Company recently constructed several miles of catenary construction on a line between Middletown and Hartford, Conn. About two miles of track were given up to trial sections of construction designed and erected by six manu-

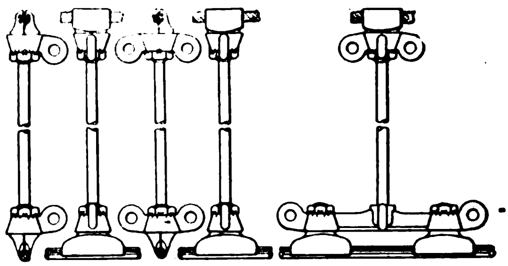


FIG. 20

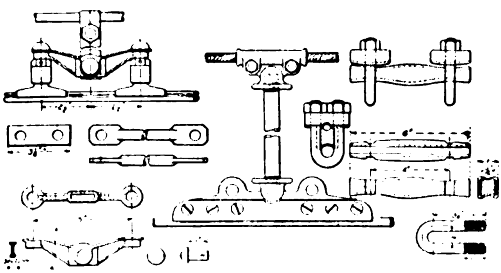


FIG. 21

facturing and supply companies, each one having a chance to erect that which it considered its best practice. Some of the designs of hangers are reproduced in Figs. 17 to 23.

It is safe to say that almost every engineer who has built a catenary line has tried his hand at devising a new catenary hanger that would combine simplicity, flexibility, certainty of grip, speed of application and adjustment, and cheapness. Fewness of parts is essential to cheapness and speed of adjustment. A hanger of five or six parts, including bolts and nuts, is preferable to one of ten or twelve parts. The grip on the

trolley wire should be powerful and easily applied. One nut only should be allowed, to tighten or loosen the trolley clamp. The hanger shown in Fig. 24 seems to answer most of these requirements.

The writer's preference is for a nut screwing down on the lower end of the hanger rod as in Fig. 24, as it can then never work off. It is desirable to have at least one pivot joint in the rod, either at the messenger or at the trolley ear. The loop type of connection to the messenger wire where the top of the

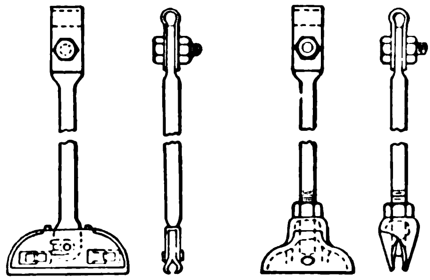


FIG. 22

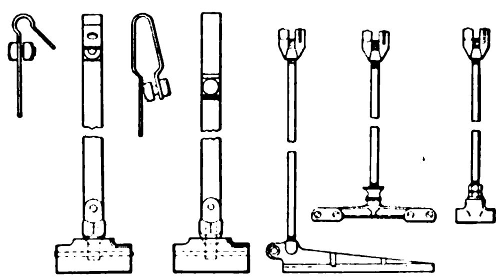


FIG. 23

rod is practically looped over the messenger wire or forms a slot for the entire hanger to work up and down on the wire as in Fig. 25, has only one drawback and that is the possibility of wearing away the galvanizing of the steel messenger cable. If the messenger be of copper the wear would probably injure the cable mechanically. This type also has the advantage of permitting the endways movement of the contact wire which will allow its tension to be well equalized on different sections of the line.

In our hunt for the best imaginable solution it must not be

forgotten that some existing solutions are operating very satisfactorily and we may sometimes do well to call a halt and ask ourselves whether all these adjustment features are really worth while, particularly if they are costly.

There is one feature of catenary design that always deserves careful attention and that is the number of different lengths of hanger rods in a span. The average railway will have more or less curvature, and spans of different lengths on the same, in which the number of inches sag of the messenger will vary considerably, though the old spacing interval of the hanger rods is ordinarily

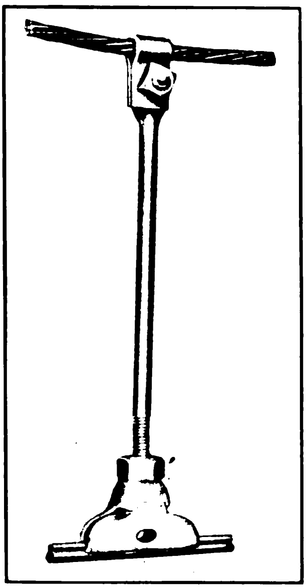


FIG. 24

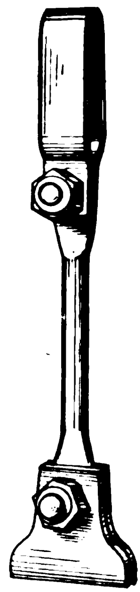


FIG. 25

uniform no matter what the distance between poles or bridges. On the Erie R.R. electrification there was little curvature and the number of different lengths of span was limited, and only six different lengths of hanger rod were needed, with 10-ft. spacing. On the Denver & Interurban there was considerable curvature; the spans varied from 120 ft. down to 60 ft. in length, spacing 10 ft., and yet there were only six lengths of hanger rod required. Three of the manufacturing companies issue catalogues or instruction books dealing quite fully with catenary construction and from the three together one can pick out most of the mechanical details necessary for equipping a line, and much

valuable information is given that will aid an engineer greatly in laying out the work. But with respect to this matter of lengths of hanger rod, shown in these catalogues, it is found that for spans from 150 ft. down to about 70 ft. one firm shows 18 different lengths of hanger rods necessary to carry in stock, while another firm illustrating spans from 150 down to 55 ft., proposes only 11 different standard sizes. A third manufacturing company shows about the same range with 14 sizes. The Rochester, Syracuse & Eastern construction requires 11 sizes. There is thus always room for the exercise of judgment in reducing the number of parts.

The vertical distance between the messenger and trolley wire at the brackets is from 20 to 23 in. on 150-ft. spans and 17 or 18 in. on 120-ft. spans. The minimum distance in the center of long spans is about 4 in. for 150 ft. and 6 in. for 120-ft. span and as much as 20 in. in a 60-ft. span when the interval between hangers is 15 ft. It is noticeable that there is a tendency toward increasing the distance between hanger points in catenary spans. It originally started at about 10 ft. One company, during the early development advocated three-point suspension on tangents for spans as long as 150 ft. At the present time however the three-point suspension is only recommended for wheel trolley operation and 11-point suspension is recommended for sliding bow operation. This brings the hangers approximately 14 ft. apart. Another company shows spans varying between 10 ft. and 13 ft. 7½ in. which is 12 points of suspension for 120-ft. span, and 11 points for 150-ft. span, as desired. A third company gives in its catalogue fittings designed for 10-ft. and 15-ft. spacing, on spans from 60 ft. to 150 ft.

The American Street & Interurban Ry. Association's Committee on Power Distribution prepared a report on catenary construction in 1908 and its conclusions were rather in favor of hanger spacing of 20 ft. to 30 ft. because the sag between hangers, though very slight, would still be sufficient to help take up the expansion of a copper trolley wire in warm weather. It was quite evident that the committee hesitated to recommend the complication of the compound catenary type of construction if any means could be adopted that would accomplish reasonably smooth operation with plain catenary construction. It also reported very favorably on making spans 300 ft. in length; that the hangers should be as light and flexible as possible and that the messenger cable should be of plow steel, strung to a small sag.

Much is said from time to time about the necessity of staggering the trolley wire from side to side when constructing for sliding bow operation. The writer has noted enough successful operation without staggering, to confirm his belief that it is not absolutely necessary under interurban conditions with average track, and motor cars of the usual interurban style. With these conditions the car is generally so sure to sway from side to side as to equalize the wear fairly well on the sliding bow. It is only where there are very heavy locomotives and extremely solid track and roadbed that the writer would entertain seri-

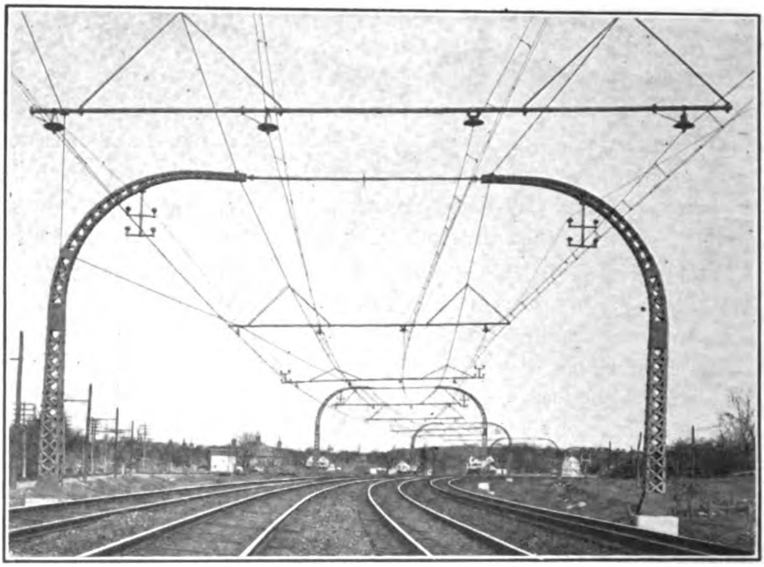


Fig. 26—New catenary construction of the N. Y., N. H. & H. R. R.

ously the necessity of staggering the wire, but though these conditions are present on the New Haven Road, the contact wires have not been staggered. Unless great pains are taken to prevent it a staggered wire always tends to pull straight and consequently to induce some sag that is not desired.

The new design of heavy catenary construction developed last year by the New Haven road is a remarkable advance in several respects, and is illustrated in Fig. 26. The chief points of interest are the following:

1. The supporting bents are much more sightly and more economical of material than the original bridges.

2. The main suspension cables of 1¼-in. stranded steel wire which carry the insulators and the messenger wires proper are uninsulated and grounded, which will facilitate maintenance, painting, etc., and will obviate much of the danger to men on the signal bridges.

3. Insulators, if broken, can be replaced by removing only three bolts, the two by which the insulator is suspended from the crossbent and the one which suspends the messenger wire from the insulator.

4. The feature of a steel working trolley wire below a copper conductor, using the elasticity of the upper wire to permit the

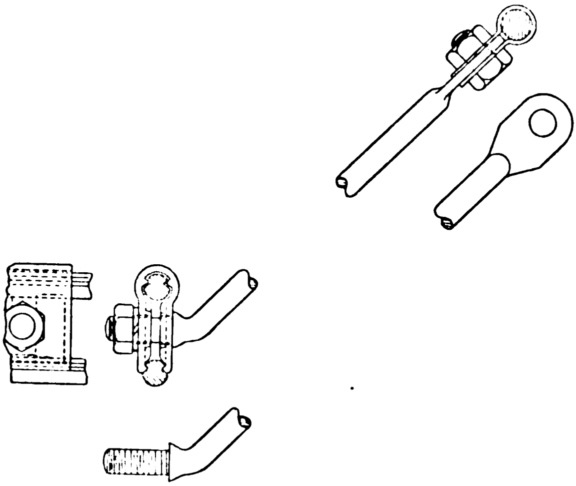


FIG. 27—Bent inclined hanger rods

contact wire to yield in an upward direction, is here repeated, showing it to be regarded as a successful means of securing smooth and reasonably flexible contact.

5. The necessity for steady-strain insulators and pull-offs of the previously accepted types on curves is entirely done away with because the hanger rods are so dimensioned that by inclining them at such an angle that the trolley wire follows the alignment of the curve exactly, the tendency is for the lower wire to pull to a curve of shorter radius than the messenger wire. By adjusting the lengths of the hanger rods with some care the curve of the center line of the track can be closely approximated by the lower ends of the hanger rods when thus inclined

and rightly adjusted for length. By bending these inclined hanger rods so that their bottom ends are horizontal, then passing the horizontal end through the middle of the clip that fastens the contact wire to the secondary messenger, the two latter are held rigidly in a vertical position and the working trolley is maintained as exactly under the secondary messenger as though it were on a straight line. See Fig. 27.

The criticism is sometimes made of steady-strain insulators for catenary curve construction that the tension under which they do their work makes the curve rigid and unyielding. In this case the heavy steady-strain insulators are dispensed with altogether, being replaced by the light iron hanger rods which for the time being are acting as steady strain insulators. Their

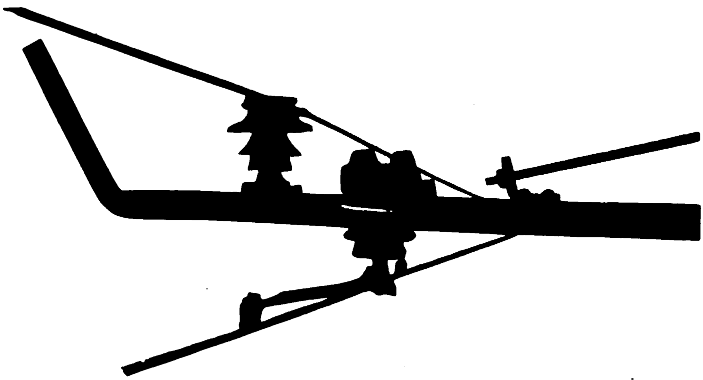


Fig. 28—Steady strain insulator, Denver & Interurban Railway

greater frequency must minimize the pull of each individual rod and tend to make the whole structure less rigid than where steady strain insulators or pull-offs are applied at intervals of 30 ft. to 60 ft.

6. The adjustments for height in this construction are extremely simple, being accomplished by slipping the suspending members of the cross bents nearer to or further from each other along the bent, thus raising or lowering it.

The features here mentioned can all be easily noted in the illustrations and should appeal as only a first-class mechanical job can to every engineer who has had to deal with overhead construction in general and catenary in particular.

Steady Strain Insulators. Steady strain insulators usually consist of a stick of treated wood shaped like a long strain insu-

lator, terminating at the outer end in a hook-shaped fitting that is attached to the trolley car, being pivoted at the inner end to an insulator on the bracket. When in this form they must be inclined upward away from the trolley wire so as to clear the sliding bow. While originally intended for curve construction only, it is often found desirable to install them at intervals along tangents say from 5 to 10 poles apart, as their presence helps to prevent swaying of a suspended trolley wire in a very high wind.

The form of steady strain insulator used on the Denver & Interurban Ry., is shown in Fig. 28. This has the merit of employing the same kind of 11,000-volt insulator that is used on the standard straight line catenary support, the head of which is cemented into a socket on the end of a malleable iron bolted to the bracket. The brace proper is a short link of malleable iron loosely hooked into an eye-bolt projecting from the bottom of the insulator. It will thus swing through an arc permitting some longitudinal movement of the trolley wire. In case the insulator breaks it will fall to the ground from the outer end of the hook, and the hook is light enough so that the stiffness of the trolley wire will make it stand out straight after the insulator has fallen and it will not hang down and foul the sliding bow.*

Between poles, various schemes for pull-offs are used, but the commonest method is to run a bridle from the upper and lower ends of the hanger spacing rods, joining the bridle wires at some distance away from the trolley and insulating the pull-off by a strain insulator. Sometimes a wood strain insulator may be put into each of the bridle wires, but care must be taken not to weight them down so that they would be in danger of fouling a bow trolley. Probably the best way to insulate a pull-off for high voltages is to use the disk type of strain insulator, which was first brought out by E. M. Hewlett in 1907. This is the handiest form of light-weight porcelain insulator and fits nicely into almost any pull-off situation. A porcelain spool has also been used as a pull-off insulator, to slip over a hanger rod. This adds weight to the trolley wire and may make a hard spot, which is undesirable for bow trolley operation if located at a point where high speed is to be made, but it is not especially objectionable on a siding or in a yard and it insulates every inch of the pull-off wire and is probably the cheapest form of pull-off for high voltages. The pull-off wire is attached directly to the middle of the spool.

* This device has been patented.

Strain Insulators. The writer's experience with catenary construction having been with high voltages, it has been necessary to be particular about strain insulators.

After some unfortunate experiences with strain insulators built up of metal and moulded insulating material of one form or another, it was found that porcelain, if it could be kept in carefully equalized compression, was the most reliable insulation, and as in the case of the straight-line insulators, a single insulator (of the heavy porcelain spool type), properly mounted, can always be depended upon. The easiest way to mount such insulators is to cement them upon a piece of pipe large enough to carry a $\frac{7}{8}$- or 1-in. bolt. If the bore of the spool is fairly large it may be

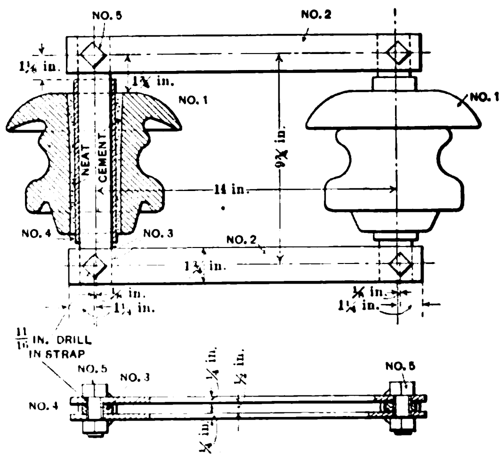


FIG. 29—Double spool strain insulator

necessary to use $1\frac{1}{2}$-in. pipe. It is more necessary to have the pipe nearly as large as the insulator than it is to have the bolt nearly fit the pipe.

The disk type of insulator is very ingenious, light and attractive but the body of the porcelain under compression is not sufficient to resist a crushing strain of more than 5,000 or 6,000 lb., or it was not when certain tests were made under the writer's supervision between two and three years ago. The $6\frac{1}{2}$-in. diameter disk insulators are now advertised to carry a safe working load of 2,500 lb. and the 10-in. insulator 4,500 lb. With the trolley tension sometimes reaching 5,000 pounds at low temperature, a strain insulator for dead ending must have a working capacity

of at least 7,500 to 10,000 lb., and it ought to be as high as 12,000 to 15,000 lb. This puts the disk type out of the running. The writer designed for the Denver & Interurban a double spool insulator comprising a porcelain spool cemented on 1½-in. pipe with 1½ by ½-in. flat iron driven through the pipe and standing edgeways to the strain, there being a hole in each end of the flat iron for linking to the other porcelain similarly fitted. This insulator, under test, carried 50,000 volts and 14,000 lb. strain simultaneously, without failure. It is shown in Fig. 29.

It is the writer's belief that, even more than in the case of direct suspension, strain insulators for catenary construction should be specified to be tested mechanically and electrically at the same time, up to their maximum mechanical and electrical capacities. It is only in this way that actual conditions of service can be duplicated in a test.

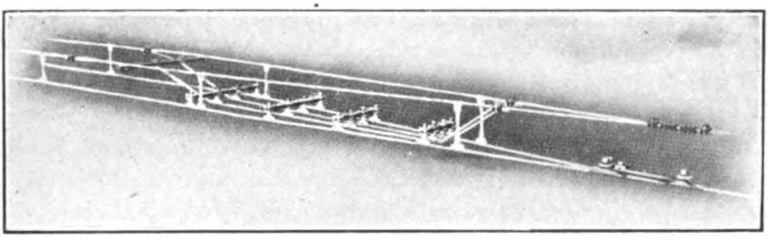


FIG. 30—Deflector

An excellent point about the disk type of insulator when used within its capacity is that there is a mechanical linkage of the guy cables on opposite sides of it which prevents their falling apart if the porcelain burns. This is not true of a wood strain insulator, which under high voltages is much more likely to get burned in two than at low tension, and for this reason the writer does not believe in using wood strain insulators for heavy strains where there is any possibility of a full voltage being applied to opposite ends of the insulator.

Deflectors and Frogs. The deflector is illustrated in Fig. 30. This contrivance has sometimes been found necessary to prevent the horns of the pantagraph bow trolley from getting tangled in the wrong wire where two trolley wires intersect on a switch or crossing. If the bow has no horns or if the horns are prolonged downwards there is no danger of a bow catching and no necessity for the deflector. In fact deflectors are about the worst

nuisance one has to contend with in maintaining a catenary line, and even where they have been carefully installed they are very apt to give trouble. It is very difficult to stretch the intermediate wires perfectly tight, and to keep them tight, even after they are adjusted.

The use of frogs on catenary construction for a sliding bow is unnecessary and when so installed they have usually been taken out afterwards.

Deflectors are heavy enough to require considerable care in setting them up, and on account of their weight, it is desirable to have them under a bracket or as near as possible to one. If not kept in good trim a bow trolley rapidly traveling underneath one will cause more or less flashing, which sometimes spreads up to the bracket, grounding the line and throwing the current off for the time being.

Section Insulators. With wheel trolleys, wood section insulators are a necessity, as in the case of direct suspension, but by far the best form of section insulator for bow trolley operation is the overlapping break without any wood or any other insulated under-run. They are also cheaper to install than the wooden insulator, there is far less weight to support, and there is no danger of warping or of destruction by fire. Section insulators make good feeding-in points and should always be fitted with a jumper which includes a knife switch, usually kept closed. When it is desired to open a section of high voltage trolley a hooked stick with a grounding chain attached above the handle is used to pull the switch, being kept hung permanently in the switch box which should be well up on a pole out of reach of all but employees. It is desirable to have such switch boxes located at railroad stations or signal towers.

On two important installations of 11,000 volts, with multiple unit car operation, no feeder wire has been found necessary and section insulators have been introduced mainly for subdividing for the purpose of more readily locating trouble. The best information for computing trolley drop in a single phase railway, and calculating feeders, is to be found in Mr. A. W. Copley's discussion of Professor Whitehead's paper on "From Steam to Electricity on a Single-Track Road," in the A.I.E.E. PROCEEDINGS for 1908.

Lightning Protection and Ground Rod. It is absolutely necessary at high voltages to ground all the brackets and spans of a catenary line. This is most effectively done by steel or iron bars

about $\frac{5}{16}$ or $\frac{3}{8}$ by $1\frac{1}{4}$ in. with the top end bolted to the butt end of the bracket and the bottom end run over to the track through the ground from the butt of the pole. The best kind of a connection to make with the track is through a cross bond, as this is more flexible than to connect a rod directly to one of the rails. The ground rods, brackets and truss rods together form a pretty fair lightning protector for the trolley construction, but to make it more effective, on the Denver & Interurban Ry. a $\frac{7}{16}$-in. steel ground cable was run on the tops of all the poles and connected to every bracket and at every fifth pole a ground rod was run down the pole and attached to a cross bond and also to a pipe or a plate ground, the latter being used when there was any moist earth near at hand. This general scheme is the cheapest

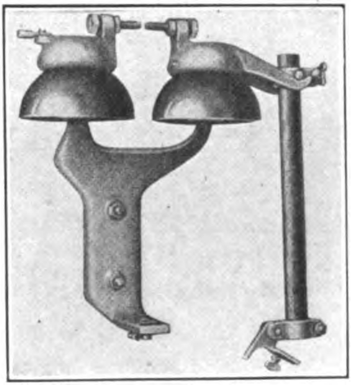


FIG. 31—Fuse type lightning arrester

method of combining the grounding of brackets and lightning protection and it has an additional advantage of stiffening the pole line considerably.

If circumstances make the use of line lightning arresters desirable, the swinging fuse type shown in Fig. 31 may be installed at intervals of a half mile. This arrester has given good service for three years on the Erie railroad, at 11,000 volts.

Splices. For a trolley wire at ordinary tension, the old forms of splicing sleeve did fairly well, but where the tension is great and the wire very stiff, as with phono-electric or steel wire, the old form of sleeve, with the necessity of curving the wire slightly in order to get it through is inconvenient, especially for emergency work. A sleeve with both holes bored perfectly straight

and inclined slightly upwards toward the center will allow the trolley to enter and pass through without binding. To insure sufficient strength. this type of sleeve is made out of rolled bronze about 1 in. square with rounded edges, as shown in Fig. 32. Experiments showed that it was not safe to depend upon a mechanical splice that involved bending trolley wire beyond the elastic limit, although such a splice would be very quick and easy to make. For splicing messenger wire, use is made of cable splicing sockets shown in Fig. 33. To absolutely prevent the messenger wire from pulling out, the ends of the strands were doubled back on themselves, the cable end pulled back hard into the socket, and babbit poured in.

Moving Contact. It is the writer's impression that the high voltage catenary construction now in use is in nearly all cases operating under conditions favorable to the sliding bow. The

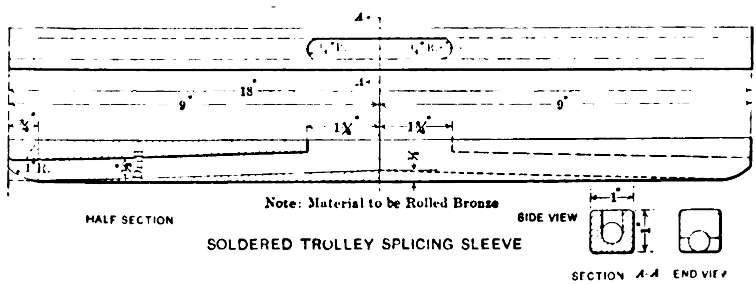


FIG. 32

conditions on the New Haven road are doubtless more severe than any other as they involve high speeds, many low bridges, and the heaviest currents yet demanded in alternating-current railway work. On nearly every other single-phase alternating-current railway the traffic is in single-car trains, or with much lighter locomotives, and at lower speeds. More skill and judgment are needed to erect and maintain catenary than direct suspension, and experience shows that the fundamental difficulties preventing smooth operation arise primarily from the expansion and contraction due to changes in temperature, which must be overcome by following some of the methods herein suggested.

Barring the tendency of the old fashioned trolley wheel to jump at high speed, even on fairly well aligned wire, it has proved a reliable contact maker up to the limit of its capacity, and has

shown itself readily adaptable to all conditions of sag in long spans. The gradually increasing use of the catenary construction with the wheel trolley, a combination which seems to be well thought of by railway operators, encourages the writer to believe that in the heavy railway work of the future on trunk lines or over long distances, where high voltage alternating current is the obvious solution, the rolling contact will tend to reassert its superiority over the sliding bow. The manufacturing companies, to whom engineers generally look for progress in such directions, cannot be said to have made much progress in this direction during the last few years. Although the writer has not been in a position to conduct any experiments with the roller type of trolley, nevertheless, in the absence of convincing proof to the contrary he is disposed to believe that it may yet be so developed as to constitute a distinct improvement over the

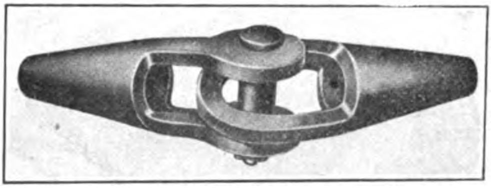


FIG. 33—Cable splicing socket

present sliding bow, in the rough and ready service which the trunk line work of the future is likely to require.

As has been the case before in some practical electrical matters, progress in this respect has had its start on the Pacific Coast. On the interurban cars of the San Francisco, Oakland & San Jose R.R. there are now in use pantograph roller trolleys of the type shown in Fig. 34. " The roller for these trolleys, which is held against the wire by a spring connected with the pantograph, is a brass cylinder 5 in. outside diameter and ⅛ in. thick. The pantagraph has a vertical movement suitable to accommodate the rise and fall of trolley wire 14 to 22 ft. above rails. This type of trolley requires little attention and the brass cylinders show an average life of about nine months on cars making 250 miles a day."* These cars are working on 600-volt direct current and have four 125 h.p. motors, so that the roller trolley

* Quoted from the *Electric Railway Journal*, Oct. 2, 1909.

evidently carries quite a respectable current. It is to be hoped that the heavy alternating current locomotive work of the future as well as the multiple unit car operation can be made even more successful than now, and the wear and tear on trolleys and line construction diminished, if the development of the roller contact trolley can only be given the attention to which it seems entitled.

The life of 67,500 miles for pantagraph roller trolleys, computed from the above quotation, seems incredible, and in the absence of detailed records may be somewhat discounted; but it is quite

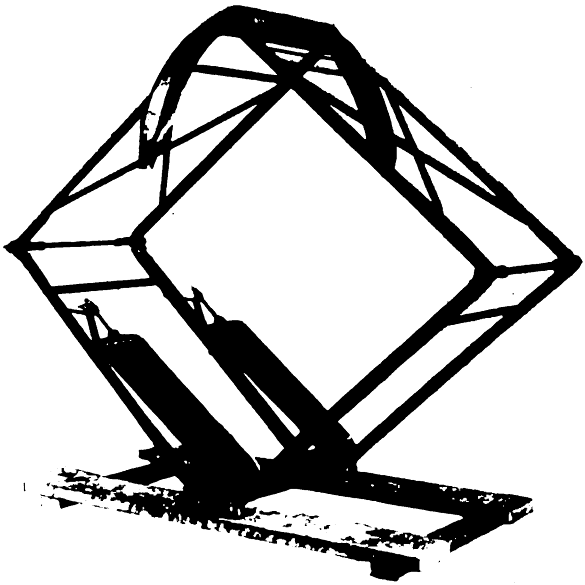


FIG. 34—Brown pantagraph roller trolley

evident that the device is worthy of consideration. The life of pantagraph shoes is variously reported as all the way from 8,000 to 15,000 miles on single-car interurban lines, and very much lower than this on the New Haven road, where the conditions of high speed, heavy currents, more rigid trolley construction and low bridges, all combine to wear them out rapidly.

Double Trolley Construction. The writer has paid no attention in this paper to double trolley construction as distinct from standard types, because it is used so little in the United States,

either in direct current or alternating current systems, that it is not at present a matter of very great interest. Where used, it is generally erected with the same types of overhead material used in single trolley construction.

The Europeans have worked it out for three phase alternating railway equipment with all the care and neatness that characterizes their construction. They seem to be willing to put up with more complications in the accomplishment of results than does the average American engineer, and the principle of adherence to form rather than simplicity in attaining a result seems to prevail both in the personal side of railway administration and in the development of mechanical and electrical ideas. This temperamental difference is further manifested in the much greater respect shown by Europeans than by Americans for law, rules, and formulæ of every kind. While the American character would doubtless profit by stricter discipline in the matter of legal observance, there are some aspects of close adherence to theoretical rules and precedents which are essentially in conflict with the necessities of American railroading, and it is very doubtful whether any American railroad man will ever become reconciled to erecting two trolley wires of opposite polarity over any railroad track, if he can possibly get along with one.

It is the writer's opinion that this one condition more than any other, will retard three-phase railway development in this country. The discussion of Dr. Hutchinson's recent interesting paper on the three-phase electrification of the Cascade Tunnel indicates that while the three-phase motor was very well adapted for severe locomotive duty, the only really unsatisfactory element in the equipment was the overhead construction, though this was partly due to certain conditions imposed upon the engineers by the railroad authorities. Single trolley operation over steam railroad tracks has now been carried on for so many years as to be practically commonplace even among railroad men; and an object lesson of a more universal type than the Cascade Tunnel will have to be presented in working order, before the present convictions of American steam and electric railway operators, with respect to the double trolley, can be changed.

In considering the development of heavy electric traction on trunk line railways, therefore, we are brought back to our starting point by the controlling influence of the working conductor:— namely, that it is the trolley system rather than the motor which is the characteristic feature of a railroad, and that that type or

system of motors will ultimately prevail which can utilize the cheapest and most easily maintained working conductor for the required conditions of operation.

For much valuable information and nearly all the illustrations given in this paper, the writer must acknowledge his indebtedness to Mr. J. J. Brennan of the Ft. Wayne & Wabash Valley Ry.; to Mr. T. H. Mather of the Rochester Syracuse & Eastern Ry.; to Mr. R. C. Thurston of the Erie R. R.; to Mr. H. W. Cowan of the Denver & Interurban R. R.; to representatives of the General Electric, Westinghouse, Ohio Brass, and Electric Service Supplies companies, to the *Electric Railway Journal* and to Westinghouse, Church Kerr & Co.

A paper presented at the San Francisco meeting of the American Institute of Electrical Engineers May 5, 6 and 7, 1910.

(Subject to final revision for the Transactions.)

TRANSMISSION LINE CROSSINGS OF RAILROAD RIGHTS-OF-WAY

BY ALLEN H. BABCOCK

It is necessary to protect:

1. The railroad communication circuits (telegraph, telephone and signal) from mechanical injury and from contact with high tension wires.

2. The train crews from personal injuries due to sagging or fallen wires.

3. The trains themselves from mechanical damage and from the liability of fire should a wreck occur at the crossing point.

4. The railroad structures from damage by fire due either to crosses between communication circuits and fallen or sagging transmission circuits, or to high potential electromotive forces induced therein by excessive unbalancing of the transmission circuits.

Having in mind the fact that contact with transmission circuits is dangerous to both life and property, it was natural that the early attempts at protection were of the nature of guard wires, in some form or other.

Many of us have had experience with some such device. Nearly all of us who have had sufficient experience have found unsatisfactory all forms of guards as yet devised. Even those of the deep basket type have failed at times to give complete protection. Furthermore, any pole line is worked at about minimum factor of safety; hence, to increase the load on it at the very point where maximum security is demanded is an engineering anomaly. Prophecy after the fact is easy.

The next step is obvious; to construct the transmission line with maximum factor of safety both in the crossing span and also in each of the adjacent spans, so that nothing short of a

general catastrophe shall bring the line into dangerous proximity to the railroad right of way. So well recognized is this principle that the power and the railroad interests are now working in harmonious conjunction to devise an economical mechanical and electrical construction for these crossing spans, so much more secure than that of the transmission line elsewhere, that if ever failure occurs it must be at some other point.

In general, it is advisable, wherever possible, to place underground all low potential power circuits, and communication circuits. The following general specifications cover the points that are now under discussion between the power and railroad companies.

General Specifications for the Construction of Overhead Electric Light or Power Line Crossings—

General

1. All crossings carrying current at more than nominal 2,300 volts to ground shall come under the provisions of these specifications, unless special conditions in large cities or otherwise shall make a modification thereof necessary or desirable.

2. Complete drawings shall be furnished in duplicate for approval before construction is commenced.

3. The power company shall give the railroad company one week's notice prior to the commencement of work.

4. All work, including the materials entering into the work, shall be subject to the inspection and approval of the railroad company.

5. The power company shall protect the railroad company against any suits for damages arising by reason of any patented devices being used in the work under these specifications.

Clearances

6. Vertical clearance, under the most favorable conditions of temperature or sag, shall be as specified by the railroad company, but shall not be less than 35 ft. above the top of rail and not less than 10 ft. above any existing wires on the right of way.

7. Side clearance for structures that it may be necessary to locate on the railroad company's right of way shall not be less than 10 feet from the center of the nearest present or proposed track.

Crossing Span

8. The crossing span shall be carried on towers or poles which shall be self-supporting under the most unfavorable conditions of loading, or of broken conductors.

9. Supports for the crossing span, and for the adjacent spans on each side, are to be generally in a straight line and preferably at right angles to the railroad.

10. Conductor supports shall be guyed away from the tracks in such manner as to make it impossible for the supporting structures to fall toward them.

11. In general, steel towers shall be used, although under certain conditions wooden structures, with concrete or other approved foundations, may be permitted.

12. Foundations shall be designed to resist double the greatest tendency to overturn under the most unfavorable conditions, due to breakage in the line or otherwise.

13. In designing tower foundations, the weight of earth shall be taken at 90 lb. per cu. ft. and the weight of concrete at 140 lb. per cu. ft.

14. When towers are used, they shall be constructed of soft or medium soft steel, thoroughly painted or galvanized.

15. Tower construction shall be shown or specified in detail on plans submitted for approval by the railroad company. They shall give sufficient data so that stress diagrams may be constructed for the given loads.

16. All steel structures on the railroad company's right-of-way shall be grounded in an approved manner and shall be provided with approved danger signs.

17. Steel structures supporting the crossing span shall have a factor of safety of not less than three, based on the ultimate strength of the material and considered under the most unfavorable conditions of loading, wind and broken conductors.

18. Wooden structures supporting the crossing span, and also wooden crossarms, shall have a factor of safety of not less than five, based upon the ultimate strength of the material and considered under the most unfavorable conditions of loading, wind and broken conductors.

All the following sections shall apply to the crossing span and to each span adjacent thereto:

Pins

19. Material: cast steel, iron pipe, malleable iron or other crude metal, galvanized.

20. Where wooden crossarms are used, a grounded metal strip must connect all pins electrically.

21. Pins shall be designed for factor of safety of three, under most unfavorable conditions.

Insulators

22. Material: porcelain only above 7,000 volts, and porcelain or glass below 7,000 volts.

23. Insulators shall be designed for voltages 25 per cent in excess of the rated working voltage of the other insulators on the line.

24. Pin type insulators shall have metal bridge caps, or the equivalent.

25. If suspended type of insulator is used, all connections between the parts of the insulator shall be of the interconnected link type, or its equivalent. Whatever type of insulator and attachment is used, the conductor must hold to the supporting structure even if the insulator is mechanically or electrically shattered.

26. Clearance: Insulators shall clear all parts of the supporting structure (except pins and crossarms), not less than 12 in. up to 24,000 volts, plus one inch per 10,000 volts additional.

Conductors

27. Material: copper, aluminum or other non-corrosive metal. For spans carrying current up to 5,000 volts, minimum size No. 6 B. & S. copper, or aluminum, or other material or alloy of equivalent strength. Above 5,000 volts, minimum size No. 0 B. & S. copper, not less than seven strands (or six strands around a non-conducting center), or aluminum, or other metal or alloy of equivalent strength.

28. Tension shall be adjusted to be equal on each side of the supports of the crossing span.

29. Clearance between conductors and tower structure (except pins and crossarms) shall be not less than 12 in. up to 24,000 volts, plus one-half inch for each additional 1,000 volts.

30. Minimum clearance between conductors shall be not less than 24 in. up to 24,000 volts, plus one inch per 1,000 volts additional.

31. The conductors shall be clamped mechanically to the insulator.

32. The conductors shall be connected to the supporting structure at an auxiliary connection that will insure positive grounding of the conductor in case of failure of the primary insulation.

33. All crossing conductors shall be wrapped or shielded against arcing where they pass over the insulators or through clamps.

34. No splicing will be allowed in any of the three spans named.

35. Crossings shall be designed for one-quarter inch ice radially of weight 60 lb. per cu. ft., plus the weight of the conductor, plus a horizontal wind pressure of 20 lb. per sq. ft. on a projected area of the ice covered cable. (Obviously where ice is never formed, that element of the calculation can be omitted.)

36. Maximum of allowable stress shall be not more than three-tenths of ultimate strength.

37. All calculations shall be based upon a temperature range of 130 deg. fahr.

The foregoing specifications are tentative in the sense that while they represent the present mutual understanding of the interested parties, they have been adopted merely as a provisional basis for discussion. As such they are submitted for the consideration of the members. It is hoped that your criticism will be construction as well as destructive.

The following table will serve to show that the subject is one not to be disposed of lightly. With 482 crossings to be legislated for on a single trunk line, it is easy to see that the agreement reached must be reasonable and equitable, or it will not stand.

CLASSIFICATION OF POWER CROSSINGS. SOUTHERN PACIFIC COMPANY

Division	Under 2500 volts	2500 to 5000 volts	5000 to 10000 volts	10000 to 15000 volts	15000 to 25000 volts	25000 to 35000 volts	35000 to 65000 volts	Over 65000	Not listed	Total
Coast	119	3	30	13	8	0	5	0	1	179
Western	47	3	9	7	3	3	42	3	3	120
Sacramento	42	6	6	0	14	0	12	5	—	85
Shasta	11	0	0	0	8	0	3	0	5	27
S. Joaquin	6	0	0	3	2	18	0	5	2	36
L. Angeles	1	0	0	0	18	6	0	0	2	27
Tucson	1	0	0	0	0	0	0	0	0	1
Salt Lake	1	0	1	2	0	0	2	0	1	7
Total	228	12	46	25	53	27	64	13	14	482

A paper read before the Philadelphia Section of the American Institute of Electrical Engineers, on March 14, 1910.

THE GENERATING SYSTEM OF AN ELECTRIC LIGHTING COMPANY

BY A. R. CHEYNEY

Under this head it is intended to touch briefly upon a few of the important considerations which may be of general interest relating to the production of electricity. The generating system here spoken of includes everything from the coal at the mine to the outgoing wires from the substations.

The main function of a lighting company is to sell electricity, and in order that it may meet with the success to which it is entitled, two facts must be kept in mind. The generating cost must be kept as low as possible, and the service must be supplied at a uniform pressure, and absolutely without interruption. Two elements are involved in the solution of the problem of cost and reliability; the physical, which follows certain fixed and unalterable laws; and, closely interwoven, the human element, as vital and as far reaching as the physical itself. This close relationship between things material and the human element is a condition that the operator has always with him, and it is most important that his conception of both be kept clear and separate.

Fig. 1 shows in graphic form some of the various details of a generating system and their relative interdependence. From the coal supply at the mine to the wires leaving the substation, one continuous, unbroken chain binds all the parts together The failure of a single link unless properly cared for, may mean the failure of all. Accident to any one of a certain class of the above composite parts may involve the system in difficulty almost instantly, as, for instance, failure of electrical machinery, underground cables, oil switches, etc. Other parts may fail

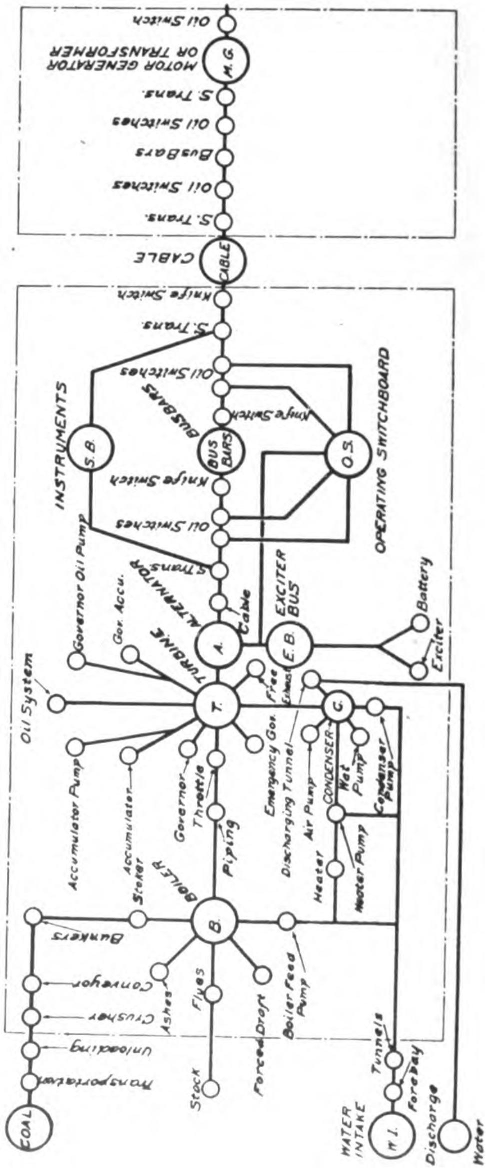


FIG. 1—Diagramatic scheme of connections of generating plant equipment.

and the system will continue to operate for a certain period, and before the danger point is reached repairs may be effected.

In any case, a break anywhere along the line must be immediately cared for. This, with large and heavy machinery, is a different proposition from the repairs to the small plant of a few years ago. Everything, including even many of the wrenches, has to be carried by the traveling crane, which, as a rule, has two hoists, in this instance one of 60 tons, and one of five tons for more rapid manipulation. As it requires a considerable length of time to have repair parts made up, in the case of our large units, it is necessary to keep on hand spare parts to a certain limited extent, at least, in order that the prolonged disablement of a main generating unit of large size may be avoided as far as possible.

If we consider the above diagram to be made out in duplicate or triplicate, properly cross connected, it will readily be seen that the stability of the system is greatly increased. This is what actually takes place in modern central station construction. Certain of the links, such as coal supply, water supply, main station bus bars, etc., as a rule, constitute single links and are depended upon for absolute freedom from trouble.

The best of our modern plants, operating under the most favorable conditions as to load factor, with steam turbines of the latest type, mechanical stokers and superheated steam, delivers about 12 per cent of the energy in the coal to the bus bars. From this must be subtracted the loss in transmission and transformation. The most efficient light known can actually make use of but about 10 per cent of this resultant energy within the range of the visible spectrum, so that we are actually converting into light but about one per cent of the energy in the coal. The efficiency of the electric motor is, of course, higher, in which case our total efficiency would reach possibly eight or even nine per cent.

The matter of load factor, as it affects the generating system, is so radically different in the cases of the gas plant and the electric plant that it is difficult to find enough in common to afford any comparisons. In the gas system, generators may be operated at maximum economy, storing the gas all the while until the demand is made for it. There is, unfortunately, no such thing as storing any small part, even, of the output of a modern central station, other than in the revolving energy of the wheels themselves.

Modern generating systems are all polyphase, and in our large cities the safe limiting voltage is fixed by the insulation resistance of the underground system. It is, of course, advantageous to have a voltage as high as possible, especially when the energy has to be transmitted to considerable distances. An underground cable that can safely carry 1,800 kw. at 6,000 volts is capable of carrying over 3,000 kw. at 11,000 volts. As the expense of the underground cable system is very heavy, this factor must be very carefully balanced against the other factor of the problem, that of absolute safety, if such a thing may be said to exist. Thus, various engineers and companies use different voltages. The Manhattan Company at 11,000 volts operates side by side with the New York Edison Company which uses 6,600 volts. The Commonwealth Company, of Chicago, operates at 9,000 volts, the Philadelphia Rapid Transit Company at 13,000 volts, and the Philadelphia Electric Company at 6,000 volts.

The elements which have most to do with the main station cost are fixed charges, maintenance expense, coal, and labor. Both the fixed and maintenance charges are practically established with the design and construction of the plant. The items of coal and labor, therefore, are the most important of those items which may be affected by proper or improper operating methods, and are the chief factors in determining the generating cost, which, in this case, is taken to include the total cost of the main and substation system. The thermal efficiency of a plant burning a high grade of coal does not differ greatly from that of a plant burning a lower grade, provided both plants are properly designed and operated. If, now, in one station we can deliver, coal to the fire room at \$1.00 per ton and in another station it costs \$3.00 per ton, uniform excellence of design being assumed, the second station cannot approach the first in generating cost.

While this cost does not by any means fix the selling cost, it is in all cases important, and, where energy is purchased in large blocks, one of the deciding factors. The relation of the generating to the selling cost is clearly shown in published reports of the Boston Edison Company, for the year ending June 30, 1909, filed with the Massachusetts Gas and Electric Commission. (*Electrical World*, September 30, 1909). This is probably a fair example of an average large central station system selling current for both lighting and power. The following table will illustrate the above relationship.

Item	Per cent of total cost
Manufacturing cost	24.60
Purchased electricity	0.02
Distribution cost	15.65
Office expenses, management, etc	15.65
Miscellaneous taxes, insurance fund charges	44.00
	100.00

Further information with regard to the above system might be of interest.

Kw-hr. generated during the year 90,877,123
Kw-hr. sold during the year 62,177,318
Ratio of energy sold to energy generated ....68.5 per cent
Coal consumed ....95,350 tons, or 2.35 lb. per kw-hr.

The total expense is 12.5 per cent of the total capitalization. The manufacturing cost including main and substations, which is 24.6 per cent of the total cost is subdivided as follows:

MANUFACTURING COST, MAIN AND SUBSTATIONS

Item	Per cent of total cost
Fuel	12.50
Rentals, real estate	0.80
Oil and waste	0.19
Wages at stations	6.18
Water	0.70
Station repairs	0.37
Steam plant repairs	2.11
Electrical plant repairs	1.74
	24.60

It must, of course, be understood that local conditions affect most materially the matter of relative costs. The possibility of reducing certain items of expense or of eliminating them altogether, such as office expense, metering and collecting, etc., has been carefully considered by central station men, and one solution is exemplified in the very low cost to street railway companies, which is given by the Commonwealth Edison Company, of Chicago, which has figured out that with careful engineering a lighting company can depend upon the increase of load factor brought about by a combination of lighting and railway loads to establish a profitable safe selling price below that at which a single plant for either lighting or railway purposes alone could

generate it. The price given in the case of certain railway load carried by the Commonwealth Company, as published, is 0.5 cent per kw-hr. plus $15.00 per kw. of maximum demand during the year, sold at the main station bus-bars.

The design and construction of any system is one of the important factors in determining the generating cost. These elements also enter very materially into the question of reliability. It is impossible for a plant of inferior design or construction to compete with one well designed, and efforts made to overcome this constant drawback by more careful and systematic operating methods are always accompanied by increased cost and possibly by chance of interruption of service. Machinery should be installed with due regard to its probable life in service. Any defective or uneconomical machinery should be discarded. A shut-down in a large system is a dear price to pay for the relatively small saving caused by retaining such machinery.

One noticeable feature in the latest station practice would seem to be the introduction of the steam turbine, not only in the case of the main generating units of the plant, but in connection with auxiliary apparatus, such as boiler feed pumps, etc. The added simplicity, great reduction in space required and also the fact that these small units combine the facility of handling of the motor-driven with the reliability of the steam-driven auxiliaries, and also that they are fairly economical in the use of steam, goes far towards recommending them for such purposes. They may be operated condensing or non-condensing as required. The steam curve of a certain 90 h.p., high pressure turbine, using steam at 175 lb. pressure, shows, at full load, 34 lb. of steam per hour, at three-quarters load, 37½ lb., and at half load, 45 lbs.

One item which should be carefully considered when any plant is projected is that there should be incorporated in its design provision for periodic testing, for measuring the steam taken by the auxiliaries, for instance, in more or less detail, for running boiler tests, etc. Without this provision, necessary changes in piping and connections in preparation for such a test involve such a considerable amount of labor and annoyance that it is quite probable that little actual testing will be carried on. In any event, the cost of conducting experimental investigations under such conditions will go far towards defeating the very purposes of the tests.

Testing may be made easy, convenient and practical. The fundamental measurements which are necessary are, of course, the weight of coal and water consumed, and the electrical measurement of the station output. The readings of the main output meters of the station should be carefully watched and the instruments regularly checked. In this connection it is important that, if possible, the instruments be checked with their respective series transformers in place. Thermometers should be installed at all important points such as in the steam lines, boiler feed lines, and in connection with the condenser equipment. The absence of proper installation for testing purposes, whether omitted for the sake of simplicity or otherwise, makes it impossible to obtain the best results.

In our modern stations we note that this matter is being very carefully considered, and provision made so that all such investigations may be conducted at a minimum of trouble and expense. The operation of a properly designed modern station thus becomes, in itself, a constant succession of tests. Regular and periodic records are kept covering the items, the information contained in these records being at times very valuable.

Several items incident to economical operation might here be mentioned. The amount of blow-off leakage should be weighed at stated intervals. The blowing down of boilers should also be carefully recorded and should find its place in the analysis of heat losses. Losses due to mechanical inefficiency of auxiliaries should be reduced wherever possible. These become a constant drain on the station, even though at times the excess of exhaust steam is necessary to heat the feed water. It is advisable, therefore, to use high efficiency auxiliaries, mostly steam driven, and, if more steam is needed at times of peak load, or even regularly during the day, to obtain it from other sources, for instance, the second-stage pressure of the steam turbine units may be made use of.

It should be observed that whatever steam is admitted to the heaters should be actually utilized therein. This means that the heaters themselves must be properly cared for and kept in an efficient condition. Exhaust piping should be carefully covered in order to prevent condensation before the steam is returned to the heaters. The condensation of the main steam lines should be known, and occasionally, if possible, it may be advisable to make a test to keep a check upon it. The firing of soft coal is best cared for by stokers, by which means regular

and efficient combustion can be maintained, the smoke nuisance is eliminated, and a saving both of coal and of labor, is accomplished. Flue gas analysis is, of course, necessary. The best method of taking samples and of analyzing is still subject to a divergence of opinion. The method of obtaining an integrated sample over an eight hour run on a boiler, or three samples per 24 hours, seems to offer many advantages. The ashes should be carefully weighed and a regular analysis made to indicate the proportion of combustible matter thrown away unconsumed. Every effort should be made to reduce this waste to the minimum and herein is an opportunity for considerable saving in very many plants.

Careful attention must be paid to loading up of the main generating units, and the same applies to the substation machinery. It is frequently good practice to put the next incoming machine on the line rather early, in the case of a rising load, and to take it off early in the case of a load which is going down.

Load factors are more directly affected by the commercial than the engineering departments of the company, yet the question of load factor is vitally important in its effect on station cost. Sufficient men and machinery must be provided to care for the maximum possible load for the day. A thunder storm may raise the load by as much as 100 per cent or more. Boilers cannot be started up at a moments notice nor can auxiliaries or main generating units. It is, therefore, advantageous to install boilers that can be operated economically over wide ranges of load. The saving possible by thus reducing the banked fire losses is considerable. If boilers and other machinery be operated at 100 per cent over rating, it is evident that the machinery in commission could be reduced fully one half in very many instances.

As an example of the above, two specific cases were taken in one of which the boilers were operated so as to carry the peak load of the station at normal rating, and in the other case the boilers were pushed at 100 per cent over rating on the peaks, an additional boiler being carried along as a reserve. The figures representing the coal used under the above conditions are as follows:

Case 1. Boilers at rating. Total coal burned 210 tons, of which 35 tons were used on banked fires, leaving 175 tons actually consumed in producing steam.

Case 2. Total coal consumed 181 tons, of which banked

fires consumed 11 tons, while 170 tons were used in producing steam. In this particular instance, therefore, a saving of 29 tons, or 13 per cent, in fuel is obtained by pushing the boilers as above stated.

One of the great advantages of certain stokers over hand fired furnaces under large boilers is the fact that the stokers can continue to operate at heavy overloads for a considerable length of time, whereas, as a rule, firemen cannot be depended on under such conditions except for very limited periods.

To illustrate the load that can be safely carried on a good boiler and to show the advantage of being able to operate a boiler at 100 per cent over rating still more plainly; consider a standard 630 h.p. boiler having 6,300 sq. ft. of heating surface and evaporating 21,750 lb. of water from and at 212 deg. fahr. per hour, or 3.45 lb. per sq. ft. of heating surface per hour. Assuming 20 lb. of water per kw. of plant output, the boiler would carry, at normal rating, a station load of 1,087.5 kw., while at 100 per cent over rating, which, as tests have shown, is not at all impossible under proper conditions, one 630-h.p. boiler would carry a load of 2,175 kw. Figuring from the factors of evaporation, assuming the feed water was being supplied at 180 deg. fahr., and that the boiler was delivering saturated steam at 175 lb. pressure, at 100 per cent over rating, and taking 2,175 kw. as the starting point, we find that by shutting down temporarily on the feed water, or in other words, resorting to the procedure well-known to all engineers of carrying water high up to peak, and leaving the peak with water slightly lower than normal, we can get an output from this same boiler from the energy stored in its own drums in the form of highly heated water, of 19½ per cent additional, or a total of 2,599 kw. This is not given as advocating the practice above mentioned, although without doubt it has probably saved more than one plant from a shut-down. The practice may be a dangerous one in a large plant. The point is, if such an increase in boiler output can be obtained by this means, it is one of the factors to be considered in the designing of our new boilers.

It is hoped, however, that the necessity for this procedure may never exist when the ideal station boiler is designed. Very many tests have been made on boilers at over rating in which very high efficiencies have been reached over wide ranges of load. In one instance at hand, a water tube boiler was operated at from 130 per cent to 190 per cent of rating with a very slight drop in efficiency.

Two factors entering seriously into the problem of reliability are the necessity for an interrupted coal supply, and also an ample supply of water for the condensers and the boiler feed pumps without chance of interruption, at all seasons of the year, and under all river and tide conditions. The lack of proper water supply is one of the reasons why the culm banks of our state have not been put to further use. The amount of water necessary in a plant of 50,000 kw., assuming 20 lb. per kw. and, in summer, 50 lb. per lb. of steam condensed, would be $50,000 \times 20 \times 50 = 50,000,000$ pounds of water per hour.

The variation in temperature of water used for condensing, due to change in seasons is considerable. Thus, not only is a very much larger amount of water necessary at certain seasons than at others, in order to obtain high vacua, but circulating pumps must be installed either in duplicate, or adapted to variable speeds, in order to care for this condition. The average temperature of the water taken from the Schuylkill River for the past year was as follows:

1909	Monthly average
January	37 deg. fahr.
February	40 " "
March	43 " "
April	54 " "
May	64 " "
June	74 " "
July	80 " "
August	79 " "
September	75 " "
October	64 " "
November	53 " "
December	38 " "
Highest temperature	84.4 deg. fahr. July 2, 1909
Lowest temperature	34.2 " " February 2, 1909

Every station should have worked out and kept in a conspicuous position—for instance, framed and hung over the desks of the chief operating men—a standard table of heat losses covering the best results that could reasonably be expected from the plant under the most favorable of conditions. This would then become an encouragement to endeavor to reach in practice the limits which theory has established. A plant operating without any detail knowledge of its heat expenditures works under a great handicap. Many of the items of heat expenditure are easily obtained. They are of very great assistance in re-

ducing unnecessary plant losses. The following comparison between the results obtained in the large turbine station of the Commonwealth Company, of Chicago, and the reciprocating plant of the Interboro Rapid Transit Co., of New York, both of which sets of figures have been published at length and frequently quoted, is of interest.

	Commonwealth Co.	Interboro R. T. Co.
	Boiler Room Losses	
Refuse in ash pit	3.0	2.4
Rejected to stack	19.6	22.7
Radiation and unaccounted for	8.0	8.0
Banking fires	5.6	
	Engine Room Losses	
Rejected to condenser	48.1	60.1
Total boiler room losses	36.2	
Total turbine room losses	51.8	
Delivered to bus bars	12.0	10.3

We note in the turbine plant that the percentage of total heat rejected to the condenser is much lower than that in the reciprocating plant, the figures being 48.1 and 60.1 respectively. This would indicate, with equivalent boiler conditions, a greater mechanical efficiency for the turbine than for the reciprocating unit. This suggests the condensing equipment. It is extremely important that the condenser installed be of the highest possible efficiency and also that it be capable of producing a high vacuum at the time of peak load on the station in order that the boiler output may be reduced to the smallest amount possible at that time. The differences in temperatures between the exhaust of the main generating unit and the discharge water of the condenser should be as low as possible.

It frequently becomes necessary to depart slightly from conditions of maximum economy in order to give proper insurance of uninterrupted service. Under no conditions can we afford a general station shut-down. It is, therefore, generally necessary during the day and up until after the evening peak, say 11 o'clock at night, to have always available on the line an extra generator in the main station. This, in a turbine plant, is very easily accomplished by bringing up a machine to full speed, synchronizing and throwing it on the line. Closing the throttle valves then gives a machine as a motor ready for instant service merely by opening the steam valve. Steam saved by thus operating

the turbine is considerable, as the remaining units may be kept at full load. It is, of course, necessary that the turbine should be allowed sufficient steam at certain intervals to keep it warm.

A first reserve unit in addition to those kept on the line, is always kept in readiness, as far as possible, with oil turned on and the condenser pump in operation ready for turning over of the main unit at a moment's notice. With regard to the substation machinery and apparatus, it is advisable that at times of heavy load this be operated well loaded rather than underloaded, thereby reducing the load at the main station as much as possible.

Another matter which has lately been claiming recognition is the regular and systematic keeping of temperature records of all electrical machinery, particularly that which is heavily loaded. One way of caring for this is to install maximum thermometers in all large machines and pieces of apparatus liable to overload, and to take from these regular weekly readings. These readings are tabulated in proper form and come to the headquarters of the operating department weekly with the inspection records. Apparatus which has been seriously overloaded and possibly not reported is then readily noted. It has been found that machines such as turbines, which have to be periodically cleaned by removing the revolving field in order to provide access to the air ducts of the armature iron which are apt to become choked up with dust and grease, are more safely operated if this record is kept, as the gradual rise in temperature due to such stoppages in the air ducts becomes evident week after week by increased values of the readings of the maximum thermometers. This dangerous condition otherwise might pass unnoticed. The method was first brought to my attention by the operating officials of one of the large New York systems.

In the matter of obtaining the lowest possible station cost consistent with reliability, I desire to call attention to a small matter which, however, may be the possible means of effecting a saving which is not always properly taken into account. Detailed costs are generally worked out in fractions of a cent per kw-hr. For certain reasons it is occasionally a good plan to work out all items of cost that pertain to the transportation, unloading, conveying, handling and firing of coal, including labor in the fire room, and ash disposal, also the maintenance of all apparatus involved in the above, including boilers, stokers, etc., as so many cents per ton of coal burned. In this way figures,

each of which is directly proportional to the coal burned, will be given more meaning to the foreman and others, than if they are expressed in small fractions of a cent per kw-hr.

For instance, it is an easier matter to make a saving on repairs to boilers or in coal handling, or any other similar items, if we can tell the head of a boiler department that his cost is 15 cents per ton of coal, than if you tell him it is 0.025 cents per kw-hr. A man will work harder to bring this 15 cents down to 12 cents than he will to reduce a very small fraction by a microscopical amount. We will thus have cost per ton at the mine, transportation, lighterage, unloading, conveying, bunker expenses, labor on the fire room floor, repairs to boilers, furnaces, and to the ash conveying machinery, and also cost of ash removal, all expressed in cents per ton of coal consumed.

And right here it might be stated that one of the best means for obtaining economical station operation is to encourage every member of the working force to take care of his particular work in the most careful and economical manner by giving him a desire to do better work and by actually giving him enough information to see that his own work is important and is being kept account of, letting him see that any change in the efficiency of his department, small or large, becomes a matter of permanent record. He thus feels that he is a factor in production and is anxious to do his best. The above method commends itself, also, in that it has absolutely nothing to do with the selling cost and the unit of energy, and is therefore a safe figure to use.

Power factor is a matter which must be carefully watched by lighting companies supplying alternating current load. There seems a tendency in spite of careful engineering, for the power factors to grow lower. It then becomes necessary at certain stages to install synchronous apparatus in sufficient amount to counteract the evil. This synchronous apparatus should be installed at the substation where the power factor is particularly low. This is frequently made possible by the installation of synchronous motors driving arc light generators, which are naturally shut down during the time of day load when the power factor is low, and thus become an extremely convenient means of increasing the power factor. Trouble with low power factors exists in a more troublesome degree in summer than in winter. This makes the generating machinery operate at high temperatures. It therefore becomes very convenient to make use of the reserve turbine unit operated as a motor with over-

excited field to reduce the current and temperature of the running machines.

Other corrections for poor power factor, outside of synchronous motors, are in the line of insuring proper voltage to motors and loading them up to the limit of safety. Low power factors are also possible by wrong connections, and in regard to the synchronous apparatus itself, it is very necessary that the substation operators be trained to run with a high power factor or leading current when required, as an under-excited synchronous motor is worse than none at all. When we consider that any load contracted for of a power factor of 50 per cent practically means a doubling of the capitalization per kilowatt involved the importance of good commercial engineering is very manifest.

The transmission system of our large companies is, in great part, underground, and it is necessary that it be as carefully installed and protected as possible. Short-circuits and high-potential surges may be encountered at any time and unexpectedly, and must be cared for. The use of choke coils in the main leads of large turbines is being urged in large 25-cycle installations on account of the necessity for protecting the switching apparatus. The short-circuits that can be obtained from present installations of turbine units in certain plants are enormous, and it is unsafe to rely upon any oil switch yet manufactured to open it. In such a case there seems to be very little choice; choke coils must be installed. On 60-cycle systems, however, the necessity for this protection is not quite so urgent, although it is quite possible that our large stations of this frequency may yet have to be thus equipped.

"The momentary short circuit current of an alternator bears to the permanent short circuit current the ratio

$$\frac{\text{armature self-inductance} + \text{armature reaction}}{\text{armature self-inductance}}$$

"In machines of high self-inductance and low armature reaction this increase of the momentary short circuit current . . . is moderate, but may reach enormous values in machines of low self-inductance and high armature reaction, as large low-frequency turbo-alternators." This is an inherent feature of the turbo-generator. "The momentary short-circuit current is from 40 to 50 times full-load current, which is a fact that in large turbine plants must be carefully considered in con-

nection with the other parts of the system and most especially in connection with switches and circuit breakers."*

In several systems, the neutral of one or more machines is grounded either through a resistance or solid, thus allowing any grounded feeder to cut itself out of commission generally under overload rather than short circuit conditions which relieves the situation somewhat with regard to oil switches. Certain indicating devices have been worked out which show any unbalanced static condition in a cable system, locating the grounded feeder before a short circuit results, and giving the operator warning to immediately cut the feeder out of commission. For an excellent description of such a device see article in the PROCEEDINGS of the A. I. E. E., October 11, 1907, Volume XXVI, p. 1619, by Mr. Torchio.

The installation provided in the case of substations for the direct current districts will generally include a storage battery reserve sufficient to carry them temporarily over any chance loss of current for a sufficient length of time to enable the operators to get the revolving machinery into commission again. Alternating-current substations are generally provided with air-blast transformers, although if the voltage is high, of course, oil-cooled transformers will be used. These transformers may have dial heads for adjustment of primary voltage if desired. Automatic regulators in which the relation between the position of the primary and secondary coils is changed automatically by means of a motor, controlled by a relay operated by a compensating voltmeter attachment calibrated for the special line drop in question, are being installed in large numbers and are giving excellent satisfaction on these 2200-volt circuits of the alternating-current distribution system.

This induction regulator is essentially a transformer, in that, neglecting the slight loss in the regulator itself, the product of volts and amperes on the primary side is equal to the product of volts and amperes on the secondary. The primary is wound for full line voltage and acts as the exciting coil, being connected directly across the line. The secondary or stationary element carries full load current and is directly in series with the line. The flux set up by the current in the primary affects the secondary or series winding according to its direction and intensity. The neutral point is where the two coils are at right angles.

* Steinmetz "Transient Phenomena", p. 201, and Proceedings of the N. E. L. A., 1909, p. 154.

Rotating the primary in either direction from the neutral impresses a voltage on the series winding which increases or decreases the line voltage as is desired. In order that the wave form may be preserved, both primary and secondary coils are designed with as many slots as possible, and, in order that the secondary may not, by the field set up by its own current, act as a choke coil, and thus lower the power factor of the regulator, the primary winding of these regulators is provided with a short circuited winding at right angles to the main winding. With the regulator on the neutral position this causes the primary to act as a short circuited secondary of a transformer so that the choking effect of the secondary flux is eliminated. The power factor of the regulator is fairly high, and as the capacity of the regulator itself is rarely more than 10 per cent of the circuit capacity its effect in reducing the power factor of a lighting load is but a fraction of one per cent.

Voltage schedules on the 2,200-volt circuits are made out by the department of distribution and forwarded to operating headquarters, giving the pressure to be maintained at the substation voltmeter with each change of load in amperes. These once in effect are not changed or departed from in any way until superseded by new schedules properly approved and forwarded to the substation. Each circuit panel carries this voltage schedule card in a card holder on the panel itself, so that it is always available for checking.

A slight use of the vector diagram will readily show that for circuits of variable power factor—for instance when the day load consists of motors giving a power factor of 70 per cent, and the night load which is mostly a lighting load, with a power factor of 95 per cent,—no one voltage schedule based on amperes alone will properly care for the voltage at the load center. In this case the voltmeter and relay control for the induction regulator must be compensated for the line characteristics. With substation voltmeters corrected by compensation for line constants, all the voltmeters in the stations will read practically alike, or the voltage at the consumers' premises, and the mental calculation of the operator in following schedules, which in a station of many circuits becomes practically impossible, is made unnecessary. The line e.m.f., of course, varies with each circuit.

The keeping of records is an important part of an operating system. The exact records to be kept and the details to be followed will necessarily vary with the size and type of the sys-

tem involved. As the system grows, detail becomes more and more necessary and the blending of the reports of the different branches into one complete whole, which will give us exactly what we may require at some future time, and yet which will avoid repetition and unnecessary labor, becomes the subject of considerable thought. First in importance, perhaps, among the operating records comes the station log book. This is a daily entry of all the main facts concerning load, engines on line, boilers in service, being repaired, cleaned, etc., pumps and their operation and, in fact, covers the operation of the plant and system. Thus, the log book for a station of 5,000 kw. would be entirely inadequate in the case of a plant of 25,000 kw., and the operating records of a 100,000-kw. plant naturally would involve greater detail than those of a 25,000-kw. plant. The object in keeping the station log book is two-fold; for assistance in laying out plans for daily operation and future growth, and secondly, for keeping on record certain important facts which may be called for at any time. In small stations these records are kept by one man as a part only of his many and varied duties. As the system grows larger this work increases so rapidly that a man will have very little to do outside of what pertains directly to his log-keeping. About this time it also becomes necessary for the data to be given to the log-keeper, as he has no time to look it up. This will be taken care of probably by the regular reports of minor departments. With a still larger system, two separate log books will be kept, one for the mechanical and one for the electrical department. The entries in these books will then be made directly by the operating men themselves and will become records at first hand. Engineers and electrical foremen operating on successive shifts will sign the log of the preceding shift as well as that of their own to put themselves on record that they have made themselves familiar with the operating conditions under the previous shift. Reports in abstract will now be taken from two log books instead of one.

Of the office records of a generating system, next in importance to the log book comes the card index system covering in detail every piece of apparatus in the system with the date of installation, first cost, order number, and a complete description, including a name-plate, serial number, etc. so that information is at hand in case replacement or spare parts are desired. This not only applies to every engine, generator, exciter, battery, etc., but to every piece of machinery and apparatus in operation

which is liable to have trouble and need repairs. It thus includes a record of all series and potential transformers, air blast transformers of alternating and direct current substations, rotary converters, motor generator sets, etc. Each large piece of apparatus bears a specific number which is entered on requisition, whenever necessary, in order that all expenses involved in connection with any piece of apparatus may be entered on record in connection with the card itself, so that at any time a system with proper records should be able to give the maintenance charge against any piece of apparatus desired, whether this is asked for yearly or after a period of years.

In order to weld the whole operating force, electrical and mechanical, main station and substations into one compact whole so that concerted action may be possible, instruction sheets specifically intended for one particular branch are distributed throughout the system. These are kept in binders provided for the purpose. Blue prints covering bus bar wiring of every station are sent to all stations for the same reason, as are also detailed prints giving the switchboard panels with every instrument, switch, etc., numbered, and covered by card in card index system as stated before. Each operator is then in a position to advise with regard to the disablement of any particular part of his apparatus by merely referring to a drawing and panel number. In this way it is frequently possible to save considerable time in making repairs and in getting reserve apparatus into commission. It also assists materially in instructing the operating force, broadening their knowledge and making them think for themselves.

In a large and complicated system it will generally happen that a miniature of the system covering every machine, bus bar, switch, cable, piece of machinery in both main and substation will be found necessary for the assistance of the main station operator. Apparatus in service and position of switches will be indicated by appropriate markings. This exemplifies the necessity for a central station operator on the main board or in close touch therewith.

Complete detailed drawings and card index should also be kept of the various piping systems, valves, etc., of the mechanical department of the generating station. All important valves of the plant should be numbered and each should also bear a tag with its number, and description of the valve. Reference to valves will always be made by numbers. In-

struction sheets are also issued in this connection with special cuts covering, for instance, detail of step bearings, middle bearings, upper bearings, of turbines, etc., showing oil grooves and general construction. In a system involving a great complexity of piping, as is necessary in plants of a large size, too much care cannot be taken that the men are carefully drilled with regard to the location and exact function of every pipe and valve, giving them a better knowledge of the complete system rather than that of only the particular part of the same in their immediate vicinity. This system of blue prints and records gives all men a chance to offer suggestions, without which feature the best of operating systems is working under serious disadvantage. Piping systems in large stations are generally painted in special colors to better designate their specific function.

With growth comes a necessary division of responsibility which necessitates an organization that will work smoothly yet flexibly in order that proper care and attention may always be given to every detail. Slight defects are occasionally found in machinery or apparatus of the method of caring for the same. These may be of more or less importance, possibly not at all dangerous in themselves, but collectively they have an influence tending to lower the standard of the station equipment. To give good and reliable service, all machinery, switches, etc., must be kept in first class condition at all times. Therefore, to guard against omissions of inspection, or any possible oversight or infringement of regular operating rules, a careful system of inspection and checking is necessary. Every piece of apparatus and every special inspection, or regular overhauling of a piece of machinery, every emergency drill and test, is cared for under specific inspection number. These are grouped according to departments and according to periods of inspection. The main inspection sheet, carrying the list of inspections necessary, is grouped into as many columns as there are week ends in the month. All inspections made, therefore, during the above week are noted by special marks opposite their names, and the initials of the foreman, engineer, or assistant making the specific inspections are required opposite each item.

At the end of every week the complete list of inspections not made or machines or apparatus not in perfect condition, rules which have not been complied with, or any departure from regularity in test or otherwise, is abstracted from the weekly detailed inspection sheet and sent to the office of the operating head by

the main department chiefs. The signing of this inspection card in itself constitutes an order to have such discrepancies corrected before the next succeeding week. No item is expected to appear on the inspection card for two consecutive weeks. The system of inspection is made absolute, and it therefore rests with the operating head whether he will accept conditions as they are, or insist upon them being corrected. The natural result of this system has been a higher ideal of excellence in both equipment and station conditions, and an increased spirit of confidence, which is essential for the best results.

Another important point which assists in maintaining a high standard of reliability is the selecting, training, drilling and re-drilling of the working force. It is not enough that the directing head be well assured that every man in his system knows his duty in times of trouble as well as when things are running smoothly, although this in itself is no slight undertaking, but he must be absolutely assured that each man will act as his best knowledge dictates under all conditions. A man can only get acquainted with accidents by experience. A majority of accidents due to the breaking down of apparatus never occurs after the first time. It will not be questioned, therefore, that the value of the operating man to the company increases directly with his length of service. There are, unfortunately, occasional accidents due to mistakes of the men themselves. As a rule these are not due to ignorance. A great majority of them are made by men who have been trained and who know better. There are times when a man's brain and hand do not act together. The elimination of this class of mistakes is a necessary step in the direction of good service. Mistakes can be made in construction and in design which may never appear excepting to a limited few, but an error in operation appears in ever widening circles, reaching possibly the remotest consumer on the company's lines.

As a fundamental requirement, therefore, we will grant that our active operating men must be given reasonable hours, good pay, reasonable prospect of advancement, as the occasion may offer, and be relieved as far as possible from worry and annoyance of any kind. Without good organization throughout the whole generating system, this is impossible.

There are thrown every year in a certain substation system, 197,000 switches, a mistake in any one of which might perhaps cause local trouble. The quality of service given by large

companies, however, shows that the errors here are comparatively few. They do, however, occur occasionally. In the main generating station of the same system there are thrown yearly some 52,000 switches. A mistake here is more far reaching in its effects than a corresponding mistake in any substation, as it may possibly involve the whole system. By exercising great care the number of mistakes of this latter kind are very few, possibly none at all being made which involve anything more than local trouble. To eliminate these few remaining errors, however, and to provide against unforeseen contingencies, a rule that every operation involving main station switching excepting in minor cases, must be checked by another operator or foreman whenever it is physically possible has given considerable ground for satisfaction.

Finally comes the choosing of the working force and the selection of the foreman, engineers and assistants. This, at first, might seem the easiest part of the whole. There are, however, very many points to be considered even in the selection of men in minor positions. It must always be borne in mind that the helper may one day be an engineer or a foreman or even more. In the choice of men for the various positions of authority, those must always be selected who have, together with other qualifications, the ability to handle men and the capacity for growth. At times the choice of a man to fill the larger positions is self-evident. In order, however, to avoid even the semblance of partiality or favoritism, it has occasionally been found a good plan to give each applicant an examination based on such attributes as a man in the coveted position should have. These will involve such points as honesty, ability to handle men, ability to achieve results, cool headedness, technical knowledge, mechanical ability and others. A sheet is prepared for each name, bearing in column form the various attributes, given, with their relative values, by the head of the department. An examining board, composed of assistants of experience, each of whom has a sheet for every applicant, places such values on each man's sheet as his own experience and knowledge of the man in question would seem to entitle him. Each name is completely marked before the second name is considered; so there can be no recollection, even unintentional, of what numbers the preceding man has obtained. The figures are then carefully added up in the office, and corresponding grades attached. It is a peculiar fact that it rarely happens there exists any real difference in opinion as to

who is the best man for the position. The value of this method, of course, lies in the fact that it is absolutely impartial. Every man on the examining board must be trained in matters pertaining to the operation of stations and central station systems in order to make it effective. The use of veto power will rarely be found necessary.

Finally, equal in importance with preserverance, whole-hearted service and painstaking insistance on high standards on the part of every man in the department, is proper company organization and recognition of faithful and efficient accomplishment.

NOTE

The following paper is to be read at the 27th Annual Convention of the American Institute of Electrical Engineers in **Jefferson, N. H., June 27—30, 1910.** This paper is to be presented under the auspices of the Industrial Power Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **D. B. Rushmore, Chairman Industrial Power Committee, c/o General Electric Co., Schenectady, N. Y.,** so that they will be received not later than June 23, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

A paper to be presented at the 27th Annual Convention of the American Institute of Electrical Engineers, Jefferson, N. H., June 27–30, 1910.

INTERACTION OF FLYWHEELS AND MOTORS WHEN DRIVING ROLL TRAINS BY INDUCTION MOTORS

BY F. G. GASCHE, M. E.

Recent innovations in the method of driving roll trains by the induction motor as accompanied by a rotor of considerable inertia effect has compelled the study of a dynamical problem of some complexity. The problem is essentially a commercial one in requiring that the mechanism involved shall exhibit the greatest return on the investment. This unavoidably imposes the consideration of the prime mover as well as the motor and equipment immediately attached to the roll train. While a complete statement of the solution of this commercial problem cannot be evolved at this time, it is the purpose of the following analysis to exhibit the manner of disposition of certain important elements.

The examination of the phenomena of motor and flywheel action by analytical processes is proposed in view of the practical impossibility of establishing the important items by the use of recording wattmeters, tachometers, or other instruments. The time intervals are so short that the inertia and other instrument defects introduce large errors even with perfectly constant voltage. Constancy of voltage with any power plant connected with a rolling mill is yet to be observed, so that direct experimental examination of the actions considered herewith is not an inviting prospect.

Roll train resistances, particularly on the heavier types of mills, are so exceedingly variable that no type of prime mover, gas engine, steam engine, or steam turbine, can withstand the sudden applications of load without the risk of troublesome, if not dangerous, speed variation unless one or more flywheels

exist in the system of motor drives. In addition to this there is imposed a high cost of conversion and the extra expense due to peak loads in the absence of flywheels.

More than this, if several large systems of roll trains are operated from a central electric power plant, it will be found, sooner or later, that it is structurally and commercially inexpedient to provide a suitable flywheel effect on the prime movers to meet the load variations on the entire system of power transmission. The shocks on the motor shaft driving a roll train are such that safe dimensions are almost forbiddingly large. Without the presence of a flywheel on the motor shaft, this shock, and the accompanying momentary demand for energy, is instantly transferred to the shaft and flywheel of the prime mover.

The motives for the application of a flywheel to a motor-driven roll train can be thus indicated:

a. Providing reservoirs of energy exterior to the power plant, in excess of the structural and commercial possibilities of flywheels on the prime movers, or of storage batteries.

b. Equipment of the roll trains with an independent means of freeing the rolls of the bars, in case the motor becomes suddenly inoperative.

c. Raising the load factor on the power plant.

d. Reduction of size and costs of installation of motors, particularly with variable roll train loads.

With reference to the first item, it may be said that the flywheel performs functions in the way of instantaneous and precisely measured delivery of energy with an efficiency of practically 98 per cent, and with a cost of installation that would make a storage battery the alternative to be avoided.

The second item is a consideration of the first importance to any practical mill man. The repetition of roll changes, involving loss of operative time, and the removal of "cobbles" or defective bars, could easily impose a financial loss that would lead to the condemnation of a given motor drive.

Item *c* is almost beyond discussion, as the approximation of uniformity of demand on the prime mover is an advantage that can be appreciated by all.

Concerning item *d*, it may be urged that the mill operation, known as a roll "pass", is accompanied by characteristics in the nature of expenditure of energy that are not to be found on any other system of electric power transmission. The nature of these resistances will be explained in what follows, but atten-

tion is directed to the consideration of an element of first importance, *viz.*, *the time required for the " pass ", as well as the time between " passes ", is established by operative mill conditions.* These time intervals are generally so short that the frequency of automatic change of controlling devices may be considered as very objectionable, if not physically impossible. The deduction from this requirement is that the " secondary resistance " of a motor cannot in general be changed to make available two forms of " slip curves " during the time required by a pass. The " torque-slip " relations having prevailed up to the instant the bar enters the rolls, these relations must continue in most cases until the " pass " has been completed. Since a certain amount of " slip " is necessary in order to realize a torque incident to the resistance of a roll train, it remains to determine how this " slip " shall be distributed over the time required for the " pass ", or a portion thereof. On first sight it would seem possible to employ the minimum of slip and use a motor exerting a torque equal to the roll train resistance when working at its most economical load. An alternative would be to use a motor of lower rated capacity, operating on a greater amount of " slip " in coming to full torque, and supplement the tardy response of the motor by the action of a suitable flywheel. If this alternative does no violence to the efficiency of power transmission, it at least favors a lower cost of installation. On certain types of small mills the first method of driving may serve a purpose with a slightly higher electrical efficiency, without the palpable exhibit of a flywheel, but the inertia effect of the rotor itself will generally in such cases be a considerable item to the advantage of the construction.

It will be shown in what follows that, *on the assumption* of perfectly rigid roll train connections and a rotor without any inertia effect (if such were possible), the induction motor is physically incapable of assuming any roll train load above the friction load that by some means may have been imposed on the motor. On the larger sizes of roll trains the shock imposed on the rolls and connections, due to the action of a powerful motor of small slip, will prove such a destructive agent that the experience will be at least a costly one. The nature of shock arising at the motor shaft can be understood from the following study of the characteristics of a roll pass. (See Fig. 1.) As the bar strikes the rolls at *a* preparatory to entering the groove, there is an increasing resistance to the driving mechanism until the

forward extremity reaches b, the smallest section of the groove. The resistance at this point b becomes a tangential effort at the roll surface remaining constant until the rear end of the bar reaches the point a at the rolls, when it diminishes to zero as the rear end of the bar reaches the point b. In addition to this resistance there is a constant resistance, due to the light running of the roll train, which must be added to the above in referring the energy requirements to the motor shaft.

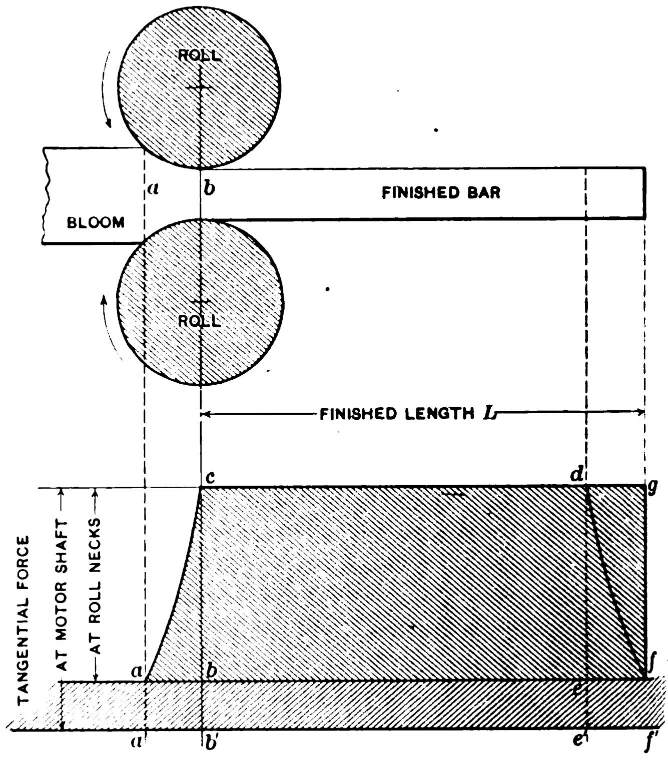


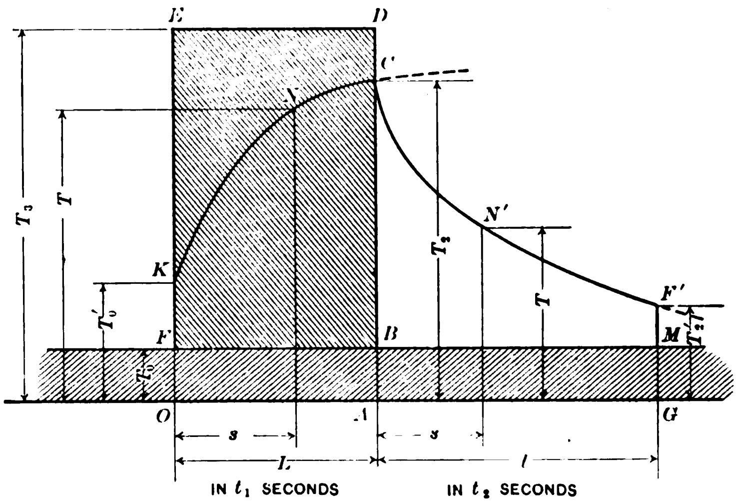
FIG. 1—Energy diagram for a roll pass

The operation of a roll pass may be represented by a diagram of energy $a'\ a\ c\ d\ f\ f'$. The "approach load" $a'\ a\ c\ b'$ is due to causes above explained, as is also the "terminal load" $e'\ d\ f\ f'$.

In some of the larger mills the portions $a\ b$ and $e\ f$ may be a large percentage of the total distance $a\ f$ for the pass. In many problems of design it is sufficient to consider the diagram of energy for a pass as the rectangle $b'\ c\ g\ f'$, thus assuming the

instantaneous rise of roll train resistance to the full value T_3. For other cases, and particularly for tapered ingots, the "approach load" $a'\ a\ c\ b'$ must be investigated as a special problem. As the necessity for this will seldom arise, the complete solution will not be introduced at this time.

It may occur at this part of the treatment of the subject that an item of leading importance must be assumed or defined before analysis of the complicated phenomena can be undertaken. This item is the tangential force due to the roll pass, which can be obtained in two ways. First, by direct experi-



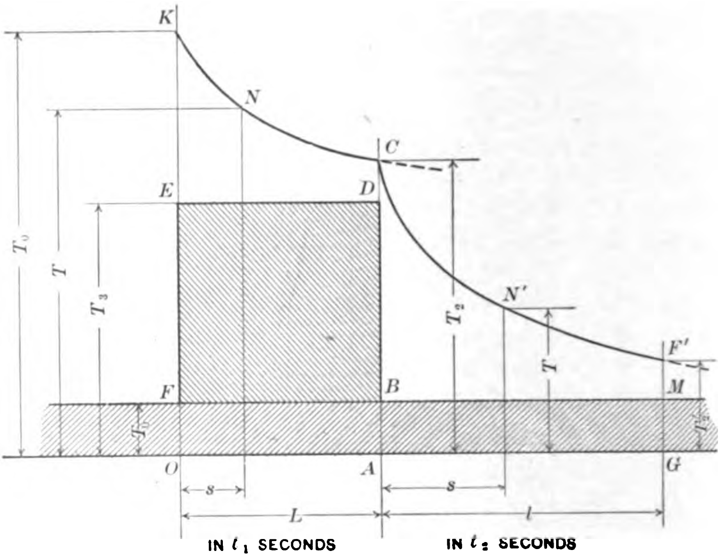
Type I—Tangential force at the motor shaft at the instant of full entry of bar into the pass is *less* than the tangential force due to the roll train resistance, *i.e.*, $T_0' < T_3$

Fig. 2—Elementary load. Rigid roll connection.

ment on existing roll trains. Second, by calculation through the use of suitable formulæ and physical constants. Assuming that by some means a definite knowledge of the energy diagram for a given "pass" is available, the considerations governing the proportions of flywheels and motors may be developed from the dynamics of the problem. Energy diagrams for mill operations may be divided into two distinct classes, illustrated by Figs. 2 and 3. The former may characterize all isolated roll trains having individual motors, in which equipment there is no possibility of a simultaneous operation in two or more grooves.

The roll "passes", so far as time of action is concerned, are completely isolated.

The latter (Fig. 3) may develop in systems of rolls driven from a lay shaft and gearing such that the simultaneous action on two or more "passes" is a possibility. This action results in certain "combination loads". The principal distinction between these energy diagrams consists of the following: The initial tangential force T_0' in Type I is less than T_3, due to the roll train, and generally greater than T_0, due to friction load. The force



TYPE II—Tangential force at the motor shaft at the instant of full entry of bar is *greater* than the tangential force due to the roll train resistance, *i.e.*, $T_0' > T_3$

FIG. 3—Elementary roll. Rigid roll connections.

T_0' for Type II is greater than T_3 by virtue of the previous history of the motor action, and is invariably the result of combination loads of a certain class. Equations (1) to (36), inclusive, exhibit the dynamical relations for these elementary loads.

CYCLICAL OPERATION OF ROLL TRAINS

With all the apparent variations of load conditions in a given mill, there is for the same class of steel product a well defined cycle of operations into which the mill equipment and its opera-

tives gravitate. The determination of the elements of this cycle, including forces in action, time intervals, etc., is capable of precision within the limits of error of the primary data, by means of equations (**1**) to (**36**) and the particularly important value of the force ${}_nT_2$ at the end of the last time interval for a mill cycle. The derivation of the numerical value of this force from the elements of the various loads composing the cycle is shown in equations (**37**) to (**43**) inclusive.

It is seen that all the formulæ are dominated by a particularly important constant A, which embodies all that is characteristic of both motor and wheel, so far as the dynamics of the problem of roll driving are concerned. Its value must be determined with some degree of accuracy, since gross errors will vitiate all of the subsequent calculations.

As an independent check on the numerical value of A the diagram (Fig. 4) has been prepared with explanatory notes, such as to favor a rapid estimate through the use of a straight edge set in two consecutive positions. The positions of the straight edge conform to the fundamental items τ, Δ_τ, v_s, and $M\,K^2$. .

There are constant for any given combination of motor and wheel, irrespective of the nature of mill loads to which they may be subject.

Analysis of Elementary Loads Shown as Type I and Type II, Assuming Rigid Roll Connections

The energy diagram (Figs. 2 and 3) for the pass is area $O\,A\,D\,E$ of which $O\,A\,B\,F$ is the portion representing the friction load due to light running of the mill. The tangential force T due to motor, never goes below T_0 corresponding to the above friction load.

Area $K\,N\,C\,D\,E$	represents energy from the wheel for Type I load and to the wheel for Type II load.
Area $O\,F\,K\,N\,C\,A$	represents energy from the motor.
Area $B\,C\,N'\,F'\,M$	represents energy from the motor to the wheel during the interval between passes.
Area $A\,B\,M\,G$	represents energy due to friction load during the interval between passes.

Notation. All forces, velocities, lengths, and times are supposed to be reduced to the action at the extremity of the radius of one foot at the motor shaft.

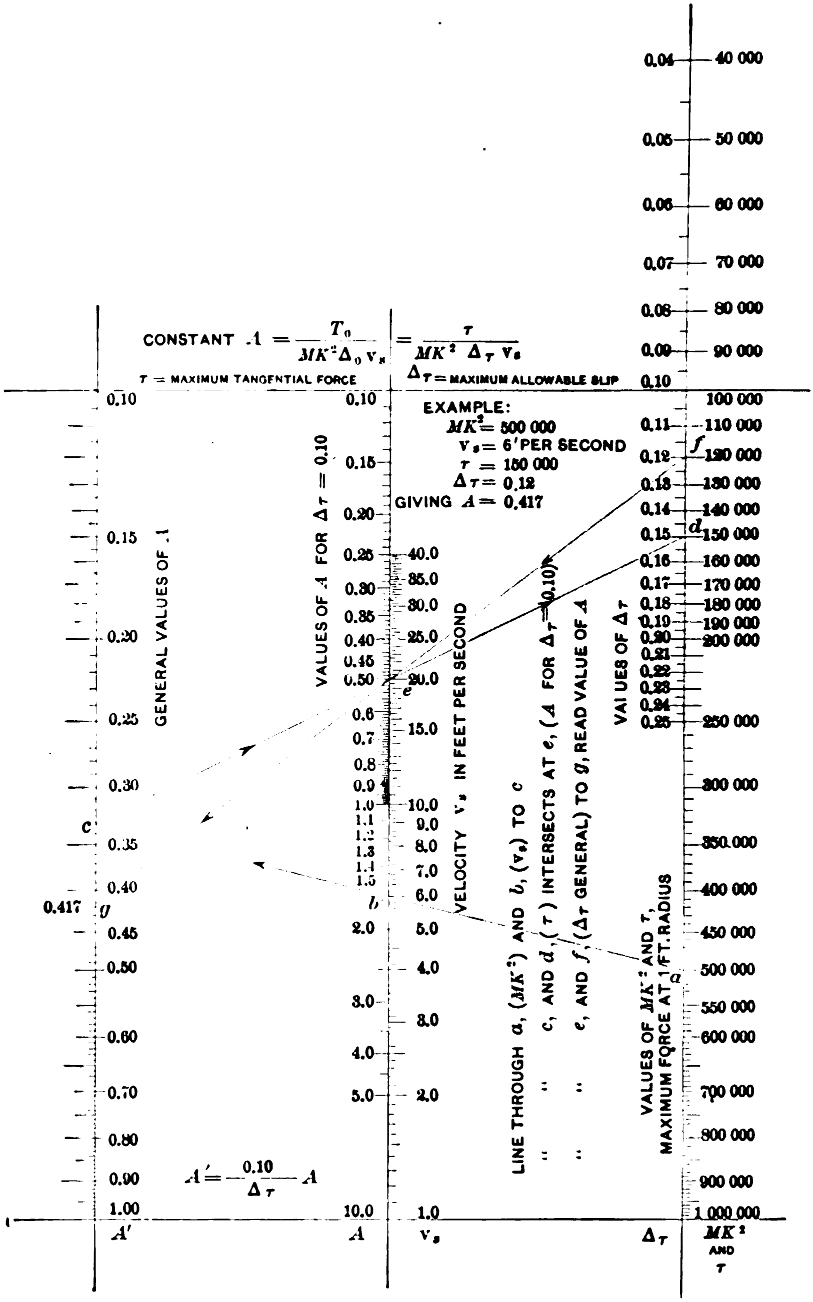


Fig. 4—Diagram for calculating constant A

K = Ratio of radius of gyration to unity for the wheel and rotating part of the motor combined.
M = Combined mass of the wheel and rotor.
L = Length of feet corresponding to the pass.
l = Length in feet corresponding to the interval.
t_1 = Time in seconds to complete the pass.
t_2 = Time in seconds to cover the interval.
v_s = Velocity corresponding to synchronous speed, ft. per sec.
v_0 = Velocity at friction load, ft. per sec.
v_2 = Velocity at the end of the pass, ft. per sec.
v_0' = Velocity corresponding to the initial force T_0'.
v = Velocity at any intermediate distance s and time t.
T = Tangential force at any instant t and distance s, pounds
T_0 = Tangential force corresponding to friction load, pounds.
T_0' = Tangential force at start of the pass, pounds.
T_2 = Tangential force at end of the pass, pounds.
T_2 = Tangential force at beginning of the interval, pounds.
T_2' = Tangential force at end of the interval, pounds.
T_3 = Tangential force due to the roll train resistance, pounds.

Type I. Relations for the Pass. From the general assumption that the decrease of velocity of the rotor, *i.e.*, the "slip" is proportional to the tangential force at unit radius, we have

$$T : T_0 :: v_s - v : v_s - v_0$$

or

$$T = \frac{T_0}{v_s - v_0}\left(v_s - \frac{d\,s}{d\,t}\right) \qquad (1)$$

from this

$$\frac{d\,T}{d\,t} = -\frac{T_0}{v_s - v_0}\cdot\frac{d^2\,s}{d\,t^2} \qquad (2)$$

The force acting on the roll train, due to the change of speed of the fly-wheel, acts in the same direction as the effort of the motor T and has a value $-M\,K^2\,\frac{d^2\,s}{d\,t^2}$ whence,

$$T - M\,K^2\,\frac{d^2\,s}{d\,t^2} = T_3 \qquad (3)$$

observing the value in (**2**) we obtain,

$$\frac{dT}{dt} + \frac{T_0}{MK^2(v_s - v_0)} \cdot T = \frac{T_0}{MK^2(v_s - v_0)} \cdot T_3 \quad \ldots (\mathbf{4})$$

which will be written,

$$\frac{dT}{dt} + AT = AT_3 \quad \ldots\ldots\ldots\ldots\ldots (\mathbf{5})$$

The integrating factor of this is ε^{At}, leading to,

$$T = T_3 + c \cdot \varepsilon^{-At} \quad \ldots\ldots\ldots\ldots\ldots (\mathbf{6})$$

when $t = 0$, then $T = T_0'$ and $c = T_0' - T_3$ .... (**7**)

i.e.

$$t = \frac{1}{A} \log_\varepsilon \left(\frac{T_3 - T_0'}{T_3 - T}\right) \quad \ldots\ldots\ldots\ldots\ldots (\mathbf{8})$$

The time for the pass is therefore,

$$t_1 = \frac{1}{A} \log_\varepsilon \left(\frac{T_3 - T_0'}{T_3 - T_2}\right) \ldots\ldots\ldots\ldots\ldots (\mathbf{9})$$

which becomes infinite for $T_2 = T_3$.

In practical applications it is frequently convenient to employ the approximate value

$$t_1 = \frac{L}{v_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{10})$$

Returning to (**1**) and (**3**) we have,

$$-MK^2 \frac{d^2 s}{dt^2} + \frac{T_0}{v_s - v_0}\left(v_s - \frac{ds}{dt}\right) = T_3 \quad \ldots (\mathbf{11})$$

or

$$\frac{d^2 s}{dt^2} + A\frac{ds}{dt} = A v_s - \frac{T_3}{MK^2} \quad \ldots\ldots\ldots (\mathbf{12})$$

$$= A\left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right]$$

Considering $\frac{ds}{dt}$ as the variable we have,

$$\frac{ds}{dt} = v_s - \frac{T_3}{T_0}(v_s - v_0) + c_1 \cdot \varepsilon^{-At} \qquad \text{........(13)}$$

when $t = 0$, then $\frac{ds}{dt} = v_0' = v_s - \frac{T_0'}{T_0}(v_s - v_0)$

and

$$c_1 = (v_s - v_0)\frac{T_3 - T_0'}{T_0} \qquad \text{...............(14)}$$

$$\therefore \frac{ds}{d \cdot t} = v_s - \frac{T_3}{T_0}(v_s - v_0) + (v_s - v_0)\frac{T_3 - T_0'}{T_0} \cdot \varepsilon^{-At} \qquad \text{(15)}$$

also

$$s = \left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right] t - (v_s - v_0)\frac{T_3 - T_0'}{A \,.\, T_0} \cdot \varepsilon^{-At} + c_2 \qquad \text{(16)}$$

when $t = 0$, then $s = 0$, and $c_2 = (v_s - v_0) . \frac{T_3 - T_0'}{A\,T_0}$.......**(17)**

Finally:

$$s = \left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right] \cdot t + (v_s - v_0)\,(1 - \varepsilon^{-At}) \cdot \frac{T_3 - T_0'}{A\,T_0} \qquad \text{(18)}$$

Substituting the value of t from (8) in equation **(18)**

$$s = \frac{1}{A}\left\{\left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right]\log_e\left(\frac{T_3 - T_0'}{T_3 - T}\right) + (v_s - v_0)\frac{T - T_0'}{T_0}\right\} \qquad \text{(19)}$$

Length of pass

$$L = \frac{1}{A}\left\{\left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right]\log_e\left(\frac{T_3 - T_0'}{T_3 - T_2}\right) + (v_s - v_0)\frac{T_2 - T_0'}{T_0}\right\} \qquad \text{(20)}$$

Types I and II. Relations for the Interval Between Passes. At the point N' with A as origin,

$$T - T_0 - M K^2 \frac{d^2 s}{d t^2} = 0 \quad \ldots\ldots\ldots\ldots\ldots (21)$$

Substituting the value of $\frac{d^2 s}{d t^2}$ from (2)

$$\frac{d T}{d t} + A T = A T_0 \quad \ldots\ldots\ldots\ldots\ldots (22)$$

leading to,

$$t = \frac{1}{A} \log_\epsilon \left(\frac{T_2 - T_0}{T - T_0} \right) \quad \ldots\ldots\ldots\ldots\ldots (23)$$

and

$$t_2 = \frac{1}{A} \log_\epsilon \left(\frac{T_2 - T_0}{T_2' - T_0} \right) \quad (24)$$

Also from (1) and (21)

$$\frac{d^2 s}{d t^2} + A \frac{d s}{d t} = A v_0 \quad (25)$$

leading to,

$$\frac{d s}{d t} = v_0 - (v_s - v_0) \left(\frac{T_2 - T_0}{T_0} \right) \cdot \varepsilon^{-At} \quad \ldots\ldots\ldots (26)$$

$$s = v_0 t + \left(\frac{v_s - v_0}{A} \right) \left(\frac{T_2 - T_0}{T_0} \right) (\varepsilon^{-At} - 1) \quad \ldots\ldots (27)$$

Substituting the value of t from (23)

$$s = \frac{1}{A} \left\{ v_0 \log_\epsilon \left(\frac{T_2 - T_0}{T - T_0} \right) - \frac{T_2 - T}{T_0} (v_s - v_0) \right\} \quad \ldots (28)$$

For particular values

$$l = \frac{1}{A}\left\{ v_0 \log_e \left(\frac{T_2 - T_0}{T_2' - T_0}\right) - (v_s - v_0)\,\frac{T_2 - T_2'}{T_0}\right\} \quad \ldots\ldots(29)$$

Type II. Relations for the Pass. The force acting on the fly-wheel is the excess of effort of the motor T above the resistance of the roll train T_3 and has a value $+ M K^2 \frac{d^2 s}{d t^2}$ whence,

$$T - T_3 - M K^2 \frac{d^2 s}{d t^2} = 0 \quad \ldots\ldots\ldots\ldots\ldots(30)$$

The differential equations derivable from (**1**), (**2**) and (**30**) are identical in form with (**22**) and (**25**), subject to the same treatment in integration; thus $T_0' > T_3$ we have

$$t = \frac{1}{A} \log_e \left(\frac{T_0' - T_3}{T - T_3}\right) \quad \ldots\ldots\ldots\ldots(31)$$

$$t_1 = \frac{1}{A} \log_e \left(\frac{T_0' - T_3}{T_2 - T_3}\right) \quad \ldots\ldots\ldots\ldots\ldots(32)$$

Similarly:

$$\frac{d s}{d t} = v_s - \frac{T_3}{T_0}(v_s - v_0) - (v_s - v_0)\,\frac{T_0' - T_3}{T_0} \cdot \varepsilon^{-At} \quad (33)$$

and

$$s = \left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right] \cdot t + (v_s - v_0)\,(\varepsilon^{-At} - 1)\left(\frac{T_0' - T_3}{A\,T_0}\right) \quad (34)$$

$$= \frac{1}{A}\left\{\left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right] \log_e \left(\frac{T_0' - T_3}{T - T_3}\right) - (v_s - v_0)\frac{T_0' - T}{T_0}\right\}$$

(**35**)

also

$$L = \frac{1}{A}\left\{\left[v_s - \frac{T_3}{T_0}(v_s - v_0)\right] \log_e \left(\frac{T_0' - T_3}{T_2' - T_3}\right) - (v_s - v_0)\,\frac{T_0' - T_2}{T_0}\right\}$$

(**36**)

RELATION BETWEEN THE FORCES AND TIME INTERVALS FOR A MILL CYCLE—CYCLICAL ACTION

$$\text{from } (\mathbf{9}) \quad T_2 = T_0' \cdot \varepsilon^{-At_1} + T_3 \, (1 - \varepsilon^{-At_1}) \quad \ldots . (\mathbf{37})$$

$$\text{from } (\mathbf{24}) \quad T_2' = T_0' \, (1 - \varepsilon^{-At_2}) + T_2 \cdot \varepsilon^{-At_2} \quad \ldots\ldots\ldots (\mathbf{38})$$

$$= T_0 \, (1 - \varepsilon^{-At_2}) + T_3 \, (1 - \varepsilon^{-At_1}) \, \varepsilon^{-At_2} + T_0' . \varepsilon^{-A(t_1+t_2)} \quad (\mathbf{39})$$

This may be transformed into

$$T_2' \cdot \varepsilon^{A(t_1+t_2)} = T_0 \, (\varepsilon^{At_2} - 1) \, \varepsilon^{At_1} + T_3 \, (\varepsilon^{At_1} - 1) + T_0' \quad (\mathbf{40})$$

For clearness of notation let

$a = A\,t_1$ and $b = A\,t_2$ using a_1, a_2, etc., for the several passes. and b_1, b_2, . . . b_n for the successive intervals.

Then, for the several passes,

$$\left.\begin{array}{l}
{}_1T_2' \cdot \varepsilon^{a_1+b_1} = T_0 \, (\varepsilon^{b_1} - 1) \, \varepsilon^{a_1} + {}_1T_3 \, (\varepsilon^{a_1} - 1) + {}_1T_0' \\
{}_2T_2' \cdot \varepsilon^{a_2+b_2} = T_0 \, (\varepsilon^{b_2} - 1) \, \varepsilon^{a_2} + {}_2T_3 \, (\varepsilon^{a_2} - 1) + {}_2T_0' \\
{}_3T_2' \cdot \varepsilon^{a_3+b_3} = T_0 \, (\varepsilon^{b_3} - 1) \, \varepsilon^{a_3} + {}_3T_3 \, (\varepsilon^{a_3} - 1) + {}_3T_0' \\
\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
{}_{n-1}T_2' \cdot \varepsilon^{a_{n-1}+b_{n-1}} = T_0(\varepsilon^{b_{n-1}} - 1)\varepsilon^{a_{n-1}} + {}_{n-1}T_3(\varepsilon^{a_{n-1}} - 1) + {}_{n-1}T_0' \\
{}_nT_2' \cdot \varepsilon^{a_n+b_n} = T_0 \, (\varepsilon^{b_n} - 1) \, \varepsilon^{a_n} + {}_nT_3 \, (\varepsilon^{a_n} - 1) + {}_nT_0'
\end{array}\right\} (\mathbf{41})$$

Bearing in mind that ${}_{n-1}T_2' = {}_nT_0'$ and finally ${}_nT_2' = {}_1T_0'$ for cyclical operation we have

$$\left.\begin{array}{l}
{}_nT_2' = \{T_0 \, (\varepsilon^{b_n} - 1) \, \varepsilon^{a_n} + {}_nT_3 \, (\varepsilon^{a_n} - 1)\} \cdot \varepsilon^{-(a_n+b_n)} \\
+ \{T_0(\varepsilon^{b_{n-1}} - 1)\varepsilon^{a_{n-1}} + {}_{n-1}T_3(\varepsilon^{a_{n-1}} - 1)\} \cdot \varepsilon^{-(a_n+a_{n-1}+b_n+b_{n-1})} \\
+ \{T_0(\varepsilon^{b_{n-2}}-1)\varepsilon^{a_{n-2}} + {}_{n-2}T_3(\varepsilon^{a_{n-2}}-1)\} \cdot \varepsilon^{-(a_n+a_{n-1}+a_{n-2}+b_n+b_{n-1}+b_{n-2})} \\
+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
+ \{T_0(\varepsilon^{b_3}-1)\varepsilon^{a_3} + {}_3T_3(\varepsilon^{a_3} - 1)\} \cdot \varepsilon^{-(a_n+a_{n-1}\ldots+a_3+b_n+b_{n-1}+\ldots b_3)} \\
+ \{T_0(\varepsilon^{b_2} - 1)\varepsilon^{a_2} + {}_2T_3 \, (\varepsilon^{a_2} - 1)\} \cdot \varepsilon^{-(\sum_2^n a + \sum_2^n b)} \\
+ \{T_0(\varepsilon^{b_1} - 1)\varepsilon^{a_1} + {}_1T_3(\varepsilon^{a_1} - 1)\} \cdot \varepsilon^{-(\sum_1^n a + \sum_1^n b)} \\
+ {}'_1T_0 \cdot \varepsilon^{-(\sum_1^n a + \sum_1^n b)}
\end{array}\right\} (\mathbf{42})$$

Multiplying each side by $\varepsilon^{(\overset{n}{\Sigma}_1 a + \overset{n}{\Sigma}_1 b)}$ and transposing ${}_1T_0' = {}_nT_2'$ we have

$$
\begin{aligned}
{}_nT_2' \left(\varepsilon^{(\overset{n}{\Sigma}_1 a + \overset{n}{\Sigma}_1 b)} - 1\right) =& \\
&\left.\begin{aligned}
&\{T_0(\varepsilon^{b_n} - 1) \cdot \varepsilon^{a_n} + {}_nT_3\,(\varepsilon^{a_n} - 1)\} \cdot \varepsilon^{(\overset{n-1}{\Sigma}_1 a + \overset{n-1}{\Sigma}_1 b)} \\
&+ \{T_0(\varepsilon^{b_{n-1}} - 1) \cdot \varepsilon^{a_{n-1}} + {}_{n-1}T_3(\varepsilon^{a_{n-1}} - 1)\} \cdot \varepsilon^{(\overset{n-2}{\Sigma}_1 a + \overset{n-2}{\Sigma}_1 b)} \\
&+ \{T_0(\varepsilon^{b_{n-2}} - 1) \cdot \varepsilon^{a_{n-2}} + {}_{n-2}T_3(\varepsilon^{a_{n-2}} - 1)\} \cdot \varepsilon^{(\overset{n-3}{\Sigma}_1 a + \overset{n-3}{\Sigma}_1 b)} \\
&+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
&+ \{T_0(\varepsilon^{b_3} - 1) \cdot \varepsilon^{a_3} + {}_3T_3\,(\varepsilon^{a_3} - 1)\} \cdot \varepsilon^{(a_1 + a_2 + b_1 + b_2)} \\
&+ \{T_0\,(\varepsilon^{b_2} - 1) \cdot \varepsilon^{a_2} + {}_2T_3\,(\varepsilon^{a_2} - 1)\} \cdot \varepsilon^{a_1 + b_1} \\
&+ \{T_0\,(\varepsilon^{b_1} - 1)\, \varepsilon^{a_1} + {}_1T_3\,(\varepsilon^{a_1} - 1)\}
\end{aligned}\right\} \quad \textbf{(43)}
\end{aligned}
$$

The above equations (**40**) to (**43**) inclusive, are general for type loads (I) and (II) with any value of the time intervals including t_2 (equation **24**) equal to zero. They, consequently, form the basis of calculating the starting force T_0' for the first pass in a mill cycle; even for combination loads.

Suppose $\varepsilon^a = 10.^\alpha$ Then $a \log_{10} \varepsilon = \alpha$

But

$$\log_{10} \varepsilon = 0.4343$$

$$\therefore\ 0.4343\, a = \alpha$$

and we may write

$$\varepsilon^a = 10^{\cdot\alpha} = 10^{\cdot 0.4343 a}$$

Hence, if we multiply each of the above exponents by 0.4343 and replace $\varepsilon = 2.71828$ by 10 we may employ the ordinary system of logarithms in the above calculations. This process may be completed once for all if we say,

$$a = 0.4343\, A\, t_1$$

$$b = 0.4343\, A\, t_2$$

Thus leading to the following system of equations for calculating ${}_nT_2'$ *viz.*,

$$
\left.
\begin{aligned}
&{}_nT_2'\,(10^{(\sum_1^n a+\sum_1^n b)}-1) = \\
&\quad\{T_0\,(10^{.b_n}-1)\cdot 10^{.a_n}+{}_nT_3\,(10^{.a_n}-1)\}\cdot 10^{.(\sum_1^{n-1} a+\sum_1^{n-1} b)} \\
&+\{T_0(10^{.b_{n-1}}-1)\cdot 10^{.a_{n-1}}+{}_{n-1}T_3\,(10^{.a_{n-1}}-1)\}\cdot 10^{.(\sum_1^{n-2} a+\sum_1^{n-2} b)} \\
&+\{T_0(10^{.b_{n-2}}-1)10^{.a_{n-2}}+{}_{n-2}T_3\,(10^{.a_{n-2}}-1)\}\cdot 10^{.(\sum_1^{n-3} a+\sum_1^{n-3} b)} \\
&+\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\
&\quad\{T_0\,(10^{.b_3}-1)\,10^{.a_3}+{}_3T_3\,(10^{.a_3}-1)\}\cdot 10^{.(a_1+a_2+b_1+b_2)} \\
&\quad\{T_0\,(10^{.b_2}-1)\cdot 10^{.a_2}+{}_2T_3\,(10^{.a_2}-1)\}\cdot 10^{.(a_1+b_1)} \\
&\quad\{T_0\,(10^{.b_1}-1)\cdot 10^{.a_1}+{}_1T_3\,(10^{.a_1}-1)\}
\end{aligned}
\right\}\quad \textbf{(44)}
$$

The influence of the exponential terms is such that it is usually unnecessary to employ more than the first three or four terms in the series for the calculation of the starting force (${}_nT_2' = {}_1T_0'$).

Energy from the Motor

From (**1**)

$$d\,s = \left(v_s - \frac{T}{T_0}\,(v_s - v_0)\right)d\,t \quad \dots\dots\dots\dots \textbf{(1a)}$$

from (**5**) or (**8**)

$$d\,t = \frac{1}{A}\cdot\frac{d\,t}{T_3 - T} \quad \dots\dots\dots\dots\dots\dots \textbf{(45)}$$

from (**22**) or (**23**)

$$d\,t = \frac{1}{A}\cdot\frac{d\,T}{T_0 - T} \quad \dots\dots\dots\dots\dots\dots \textbf{(46)}$$

from (**1a**) and **45**

$$d\,s = \frac{1}{A}\left[v_s - \frac{T}{T_0}\,(v_s - v_0)\right]\cdot\frac{d\,T}{T_3 - T} \quad \dots\dots\dots \textbf{(47)}$$

The energy from the motor during the pass in foot pounds is,

$$\int_0^L T\,d\,s = \frac{1}{A}\int_{T_0'}^{T_2}\left[v_s - \frac{T}{T_0}\,(v_s - v_0)\right]\frac{T\,d\,T}{T_3 - T} \quad \dots\dots \textbf{(48)}$$

$$= \frac{1}{A}\left\{\left[(v_s - v_0)\,\frac{T_3}{T_0} - v_s\right]\left[T_2 - T_0' + T_3\,\log_e\frac{T_3 - T_2}{T_3 - T_2}\right]\right.$$

$$\left. + (v_s - v_0)\,\frac{T_2^2 - (T_0')^2}{2\,T_0}\right\} \quad \dots\dots\dots \textbf{(49)}$$

Substituting the value of L from (**20**)

$$\int_0^L T\,d\,s = T_3\,L - \frac{1}{A}\,(T_2 - T_0')\left[v_s - \frac{T_2 + T_0'}{2\,T_0}\,(v_s - v_0)\right] \quad (\mathbf{50})$$

Similarly, from (**1a**), (**46**) and (**29**) we obtain:
The energy from the motor during the interval in foot pounds

$$\int_0^l T\,d\,s = T_0\,l + \frac{1}{A}\,(T_2 - T_2')\left[v_s - \frac{T_2 + T_2'}{2\,T_0}\,(v_s - v_0)\right] \quad (\mathbf{51})$$

In view of the following statements equations (**54**) and (**55**) we may say:

$$\int_0^L T\,d\,s = T_3\,L - \frac{M\,K^2}{\tau}\,\Delta_\tau\,v_s^2\,(T_2 - T_0')\left[1 - \frac{T_2 + T_0'}{2\,\tau}\,\Delta_\tau\right] \quad (\mathbf{50a})$$

$$\int_0^l T\,d\,s = T_0\,l + \frac{M\,K^2}{\tau}\,\Delta_\tau\,v_s^2\,(T_2 - T_2')\left[1 - \frac{T_2 + T_2'}{2\,\tau}\,\Delta_\tau\right] \quad (\mathbf{51a})$$

$$\int_0^L Tds + \int_0^l Tds = T_3\,L + T_0\,l + \frac{M\,K^2}{\tau}\,\Delta_\tau v_s^2\,(T_0' - T_2')\left[1 - \frac{T_0' + T_2'}{2\,\tau}\,\Delta_\tau\right] \quad (\mathbf{51b})$$

Note on the Value of the Constant A

$$A = \frac{T_0}{MK^2(v_s - v_0)} = \frac{T_0\,\frac{v_s + v_0}{2}}{\frac{1}{2}M(K^2 v_s^2 - K^2 v_0^2)} = \frac{1}{\theta} \quad \ldots .(\mathbf{52})$$

where θ is a time in seconds.
Thus: θ is time required for the force T_0 acting with a mean velocity $\frac{v_s + v_0}{2}$ to deliver the energy corresponding to that absorbed by the wheel when the velocity v_0 is increased to v_s, *i.e.*,

$$\frac{1}{2}\,M\left[K^2\,v_s^2 - K^2\,v_0^2\right] = T_0\,\theta\,\frac{v_s + v_0}{2} \quad \ldots\ldots\ldots(\mathbf{53})$$

Assuming that the nature of roll train loads gives evidence of the maximum tangential force τ which will be imposed on the motor, and that the corresponding velocity is v_τ, then equation **(1)** gives

$$\tau : T_0 :: v_s - v_\tau : v_s - v_0$$

i.e.,

$$v_s - v_0 = \frac{T_0}{\tau}(v_s - v_\tau) = \frac{T_0}{\tau} \triangle_\tau v_s \qquad \textbf{(54)}$$

where $\triangle_\tau$ is the maximum allowable slip in per cent of synchronous speed corresponding to the maximum force τ whence from **(52)** and **(54)**

$$A = \frac{\tau}{M K^2 \triangle_\tau v_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(55)}$$

While the commercially advisable slip for a given equipment of power plant motors and transmission lines is always a local problem, it seems to be the evidence of recent large installations that $\triangle_\tau$ lies in value between 0.08 and 0.12 and may be accepted in preliminary designs at $\triangle_\tau = 0.10$ whence

$$A = \frac{10\,\tau}{M K^2 v_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(56)}$$

NOTE

The following paper is to be read at the 27th annual convention of the American Institute of Electrical Engineers in **Jefferson, N. H., June 27—30, 1910.** This paper is to be presented under the auspices of the Telegraphy and Telephony Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **William Maver, Jr., Chairman Telegraphy and Telephony Committee, 136 Liberty St., New York,** so that they will be received not later than June 23, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting.

A paper to be presented at the 27th Annual Convention of the American Institute of Electrical Engineers, Jefferson, N. H., June 27–30, 1910.

TELEPHONE ENGINEERING AROUND THE GOLDEN GATE

BY ARTHUR BESSEY SMITH

The telephone requirements of a large city differ in certain essential points from those of a city of small or moderate size. The chief of these are as follows:

Measured service.

Private branch exchange service.

Interborough service.

Although these exist to some extent in smaller places, they are peculiarly important considerations in the telephone service of a large and congested city. They are practically the conditions which had to be met by the automatic telephone exchanges installed in Oakland and San Francisco, California. For this reason it is felt that a statement of the chief engineering problems of these cities and how they were solved will be of general interest.

The Setting. The interest in the region of the Golden Gate centers about two cities, San Francisco and Oakland. The former is a thriving seaport of about 350,000 inhabitants. It occupies the rough, hilly, northern end of the small peninsula (see Fig. 1) which separates the southern end of San Francisco bay from the Pacific ocean. The rather sandy region south of the city is thinly populated. The north peninsula across the Golden Gate is more thickly settled. To the eastward across the bay lies the city of Oakland, in the pleasant region between the Berkeley hills and the water. Oakland has a population of over 250,000 while Berkeley, Alameda and other smaller cities have about 60,000 inhabitants. The total population of the region reaches well up to three-quarters of a million.

San Francisco is a cosmopolitan city. There are Chinese,

Italian and Latin quarters, each with its distinctive population and language. The wharves lie along the eastern edge of the city, with a great wholesale and manufacturing district south of the business center. Although a large amount of manufacturing is carried on, the harbor and shipping facilities have located the city and made it what it is.

Oakland has had a rapid growth since the earthquake across

Main office, San Francisco

the bay and is second only to San Francisco in business importance. The cities are very closely bound together by business relations and also because so many business men of San Francisco live in Oakland. North of Oakland is Berkeley, the seat of the State University of California. Oakland also has considerable Chinese population, enough to warrant the serious attention of the telephone engineer.

The Problem Stated. The requirements to be considered in designing a telephone system for this region may be briefly stated as follows:

1. A system which shall give satisfactory telephone transmission between all points in the whole territory.

2. A system which provides satisfactory accessory conditions such as ease, rapidity and accuracy of completing and controlling connections, methods of charging for service and means for discrimination in the same.

The consideration of these general requirements as applied to the case in hand causes their expansion into ten conditions. *viz.*,

1. Quiet, clear, transmission over all talking circuits.

South office, San Francisco

2. Easy, quick and accurate completion of local connections within each exchange district.

3. Provision for the cosmopolitan nature of the population especially regarding the diversity of languages.

4. Measured service.

5. Free service on calls to certain classes of stations.

6. Private branch exchange business.

7 Quick and accurate completion of calls between exchange districts especially between San Francisco and Oakland.

8. Accuracy in charging the accounts of credit toll users.

9. Credit and cash toll work between exchanges.

10. Provision for the harmonious mutual working of different types of apparatus used in the several exchanges.

A Bit of History. In the Spring of 1905 the interest of San Francisco citizens was aroused by a small exhibit of the auto-

matic system. This exhibit was, however, destroyed by the earthquake and fire in the spring of 1906. While the city was recovering from the effects of the disaster the attention of constructionists was diverted to Oakland where an automatic system was installed and completed in May, 1907. It is of the three-wire trunk release common battery type, with Keith type line switches. Three offices are in service, Main East and Berkeley, with two district stations connected to the Main office.

Work was again taken up in San Francisco with the result that a system was installed in 1909. By the time the San Francisco order was placed the two-wire automatic equipment has been perfected and was accordingly used. Four offices are at present operating and are designated as Main, Howard, South and West.

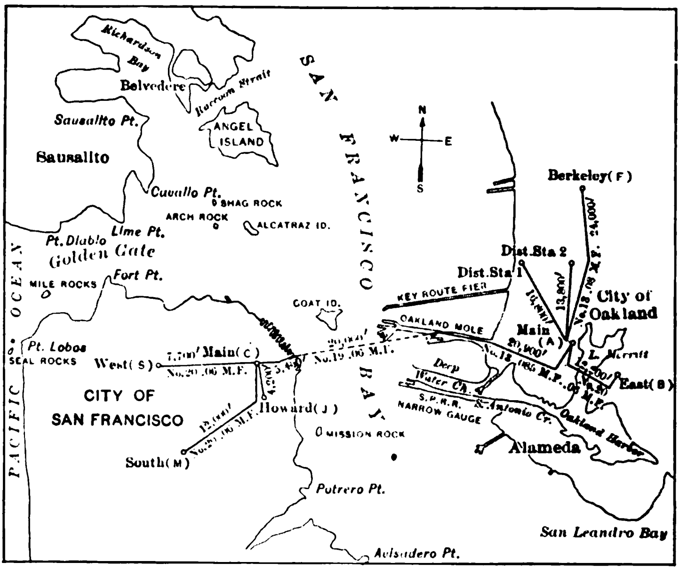


FIG. 1—Map of San Francisco and Oakland

LOCAL EXCHANGE APPARATUS.

Oakland. The locations of the offices in Oakland are shown in Fig. 1. More extended and detailed descriptions of local exchange apparatus have been given from time to time, hence my references will be confined to recalling the types and chief functions of the several switches, in order that the subjects discussed may be more clear.

Each subscriber's line in any office terminates in a line switch (Fig. 2). These line switches are grouped in units (see Figs. 3 and 4) of from 50 to 100 each. All the line switches in a unit have access to a group of ten trunk lines. The general arrangement of switches is shown in Fig. 5. When any subscriber initiates a call, his line is automatically connected to an idle trunk line, *a*. This trunk is preselected, so that there is no loss of time, the connection being practically instantaneous. The various groups of ten trunks each, which come from the banks of the line switch units, terminate in first selector switches.

To the first or bottom level of bank contacts in all first se-

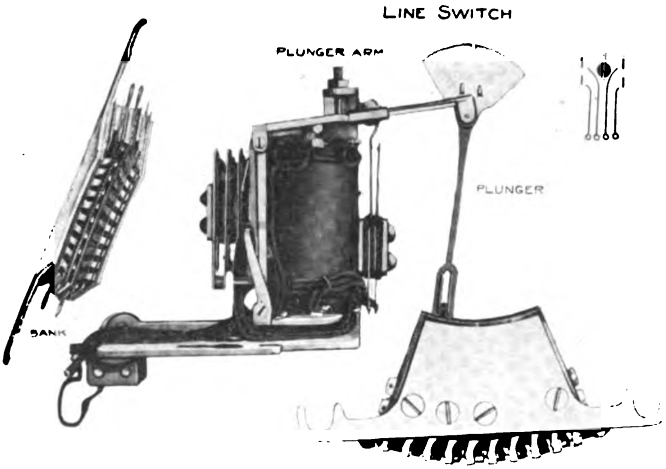


FIG. 2

lectors in Oakland are attached trunk lines leading to the Main office. The second level has the trunks leading to the East office and the third level those to the Berkeley office. Taking the East office for example, the trunks from the second level are termed local trunks, *b*, since they run to second selectors in the same office. Those from the first and third levels, however, are outgoing trunks, *c*, for they run to the other offices, Main and Berkeley. These outgoing trunks go through repeaters, which serve the chief purpose of supplying talking current to the calling subscriber from his own office, while still enabling him to send impulses to the distant office to control the switches.

The second selectors in each office have the duty of picking out the desired thousand group and of selecting an idle third selector in that thousand. The third selector chooses the hundred group and the connector makes the final connection to the line of the called subscriber. In practice the connector switches are mounted on the same frame with the line switches with whose lines they connect. Incoming trunks, *d*, from other offices are wired to second selectors whose banks connect with trunks common to the local apparatus.

The means by which a subscriber controls the switches is

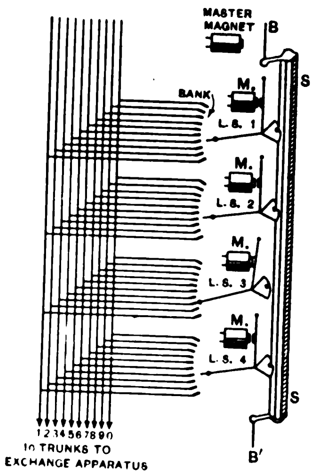


FIG. 3—Grouping of line switches

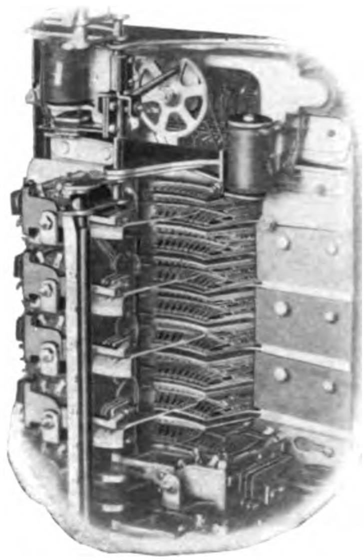


FIG. 4—Close view of line switch unit

briefly reviewed here to make clearer the operation of the special functions to be described later. The two line wires which extend from any Oakland office to a subscriber's station are termed "vertical" and "rotary" respectively. In the office each is connected to a relay which has its other terminal attached to a battery of storage cells. The other (positive) terminal of the battery is grounded. The dial or calling device at the substation, when operated, grounds each wire in a definite way, operating the relays, and through them the switches.

The vertical wire is the impulse transmitting member, for

over it are sent at various times the exact number of impulses required to set the switches according to the digit called. The rotary wire is the switching or circuit-changing member. It determines upon what switch or magnet the vertical impulses shall act. At the close of any series of impulses over the vertical wire, one impulse is always sent over the rotary wire to shift the connections in the switches so that the next series over the vertical line will be effective on the next operation to be performed.

When the called subscriber answers, a relay in the connector is operated which switches the rotary wire from negative to

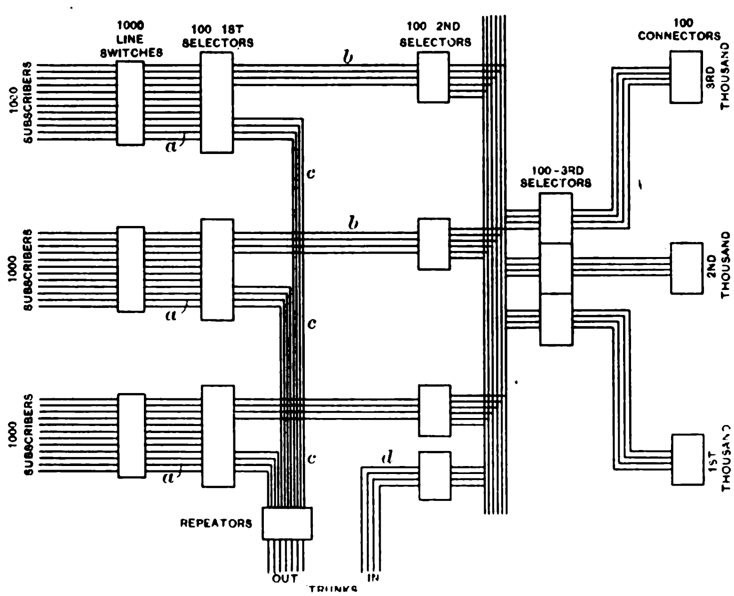


FIG. 5—Trunking in Oakland

positive battery, thus supplying talking current to the calling subscriber.

The simultaneous grounding and clearing of both vertical and rotary lines causes the switches to be released and restored to normal position.

San Francisco. The relative locations of the four offices are shown in Fig. 1. The grouping of switches is somewhat different from that of Oakland owing to the introduction of secondary line switches. A typical arrangement is shown in Fig. 6.

Each subscriber's line terminates in a primary line switch.

These switches are grouped in units of 50 each, and have access to ten trunks, as described for Oakland. But here the difference begins. The trunks from the primary line switches are carried to secondary line-switch units, where each trunk terminates in a secondary line switch. Each unit group of secondary line switches has access to a group of ten trunks, *d*, each of which ends in a first selector. These secondary line switches are exactly like the primary switches in function, for they pre-select the idle trunks in exactly the same way.

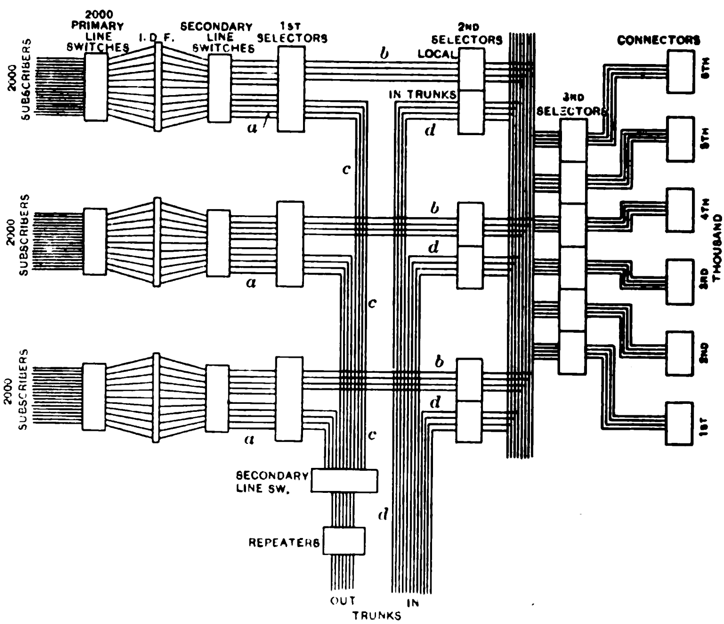


FIG. 6 —Trunking in San Francisco

The purpose of using primary and secondary line switches is to enable any subscriber's line to use any first selector switch. This is in the interest of economy. Where only a small number of trunks are available for selection, the efficiency is relatively low. For instance, it has been found in automatic telephone work that ten trunks in one group can be depended upon to handle about 225 busy-hour calls, or 22.5 calls per trunk. Twenty trunks in one group will handle about 575 busy-hour calls or 28.75 calls per trunk. By arranging one hundred first selectors in one group 4,000 busy-hour calls may be successfully handled.

If arranged in groups of ten each it would take about 180 first selectors to carry the same load.

The intermediate distributing frame placed between the primary and secondary line switches is to render more easy the interconnections by means of which the traffic is equalized on all the first selectors.

Since the first selectors select the office in which the called number is located, all levels but one will be connected to trunks to other offices. These outgoing trunks, *c*, are led through secondary line switches so that any inter-office trunk is made available to any first selector. For instance, if we consider a call from Main to South, every trunk leading to the South office from Main will be available for use by every first selector in the latter office. By arranging all the trunks in a common group, considerable saving in trunk cable is secured. Though varying with the local conditions, the saving has in certain cases been as high as 40 per cent.

The incoming trunks, *d*, from other offices terminate in second selectors which have access, in common with local second selectors, to third selectors. The grouping from here on is identical, in general, with that of the Oakland Exchange, and the connectors are mounted on the same frames with the primary line switches, whose lines they are designed to reach.

The exact method of operation differs radically from that used in Oakland, for the San Francisco apparatus is controlled by the subscriber over two wires with no earth return. This greatly sinplifies the subscriber's telephone and gives many structural and operating advantages.

The two subscriber's line wires are known as positive and negative, indicating the terminal of the battery to which each is attached through the windings of the line relay. The series of impulses for stepping up the wipers of the switches is caused by the dial or calling device, which opens and closes a normally closed pair of contacts. The line relay follows these impulses and repeats them to the magnets which move the wiper shaft.

The switching of the circuit to the next switch or operation depends upon the time interval between one series of impulses and the next. During a series, the circuit-changing member is held by a catch, which is released when the impulses cease to come. The release is accomplished by simply opening the line circuit by hanging up the receiver. This momentarily brings into action the release magnets which restore all switches to normal.

1. *Telephone Transmission.* The nature of the completed circuit between two subscribers has a vital effect on the quality and loudness of transmission. Freedom from external disturbances is to be secured by properly transposed wires and perfect electrical balance. The former is secured by a large use of telephone cable, the latter by high insulation and properly designed apparatus. In the telephone switchboards installed in San Francisco and Oakland every talking circuit is balanced from one end to the other. Fig. 7 gives in simplified form the transmission circuit between two subscribers in separate offices. From the calling telephone to the called telephone there are four "bridges" or shunt paths. Each of these is a relay or a pair of relays, all of which are highly inductive, so that little loss is occasioned to telephone current. The impedance of each path from line to earth is made as nearly as possible equal to that of the mate. No extra coils are bridged to one side of the

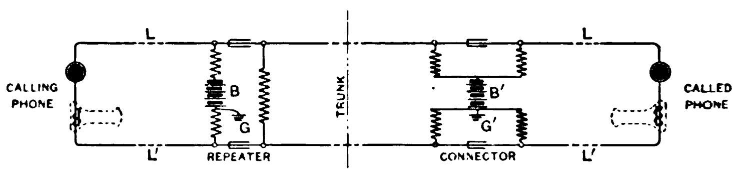


FIG. 7—Simplified talking circuit. Inter-office

line, and none are inserted in series. All auxiliary circuits are handled by a third wire within each office, leaving the talking circuit clear for its proper functions. The trunks are two-wire with no earth return circuits during conversation. Each subscriber is supplied with talking current from a battery in his own office. No repeating coils are used in any portion of the circuits.

2. *Method of Calling.* The method of calling a number on the automatic system has been described by others. Briefly, it consists in rotating a small dial by the finger, making one motion for each digit in the call number. The dial used in San Francisco is shown in Fig. 8. To assist the memory, the offices are designated by letters instead of figures. The code is as follows:

C Main office.
J Howard office.
M South office.
S West office.

Thus, a telephone whose number is 22785, appears in the

directory as J-2785. It is served by the Howard office, though this is of little importance to the subscriber.

The manipulation of the dial for an average call number takes about five seconds, after which the bell of the called station begins to ring without further action on the part of the calling subscriber. The ring is intermittent and ceases when the called subscriber answers.

Instantaneous release of the switches is effected by hanging the receiver on the hook. This is of interest chiefly to those who have two or more calls to make in succession.

3. *Diversity of Languages.* The method of calling above described is of special convenience to the many people who speak only foreign languages. The Arabic numerals are common to practically all nationalities represented in San Francisco except

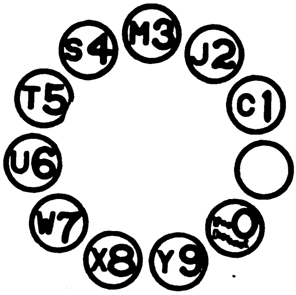


Fig. 8—San Francisco dial

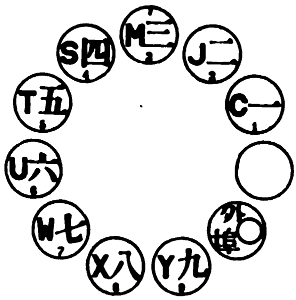


Fig. 9—Chinese dial

the Chinese. For the latter a special lettering has been made which is shown in Fig 9.

4. *Measured Service.* One of the conditions met in managing a telephone system in a large city is the desirability of charging for the service in proportion to the amount of service rendered. This is ordinarily done by attaching a meter to each subscriber's line. The requirements of a meter are as follows:

1. It must register only once for each completed connection, rejecting those in which the called station fails to answer.

2. It must make no charge for connection to certain classes of telephones, such as fire, police, information and complaint desks, etc.

The Oakland exchange is operated on the flat rate basis for all calls originating and terminating within the exchange, which includes the suburb of Berkeley. In San Francisco measured service is required.

The meter in an automatic telephone system is attached to the line switch. As above mentioned, it must not operate until the called station answers. Therefore, the latter act must cause some change in electrical condition at the line switch which will cause the meter to register. The line switch of the calling station and the connector which picks up the called line may be in different offices with 1st, 2nd, and 3rd selectors and a repeater in the circuit between. The called station can control the connector and through it the condition of the line leading back to the line switch. Two changes in condition are available, reversal of current and change of current strength. The latter is undesirable on account of its interfering with conversation to stations set aside for free service. The former seemingly necessitates some form of polarized magnet. As it was desired to avoid the use of permanent magnets, a two-coil meter was devised. It is so arranged that when the called station answers, the current supplied to the latter operates the relay which reverses the current supplied to the calling line. This causes the meter to record one call. Neither coil alone will cause registration, and the apparatus has a range from 0 to 1,500 ohms line resistance. Its line coil is of low resistance and is short-circuited during conversation. The reversal of current for operating the meter is accomplished in such a manner as not to cause inconveniences to the calling subscriber.

5. *Free Service.* Since the connector is the switch in which occurs the reversal of current which operates the meter, the means for giving free service must effect this part of the apparatus. It is done by grouping all free service lines such as information, police, etc , into one or more hundred groups, each group served by a set of connectors. All these connectors are so wired that the current flow to the calling subscriber is not reversed when the called station answers, consequently no register is made.

There is one class of calls for which, strictly speaking, no charge should be made, and that is calls which result in the wrong number being obtained. The meter makes no discrimination here, and if the called station answers, a call will be recorded. However, experience has shown that such a small per cent of wrong numbers are obtained that they may safely be neglected. This is especially true if wrong calls due to carelessness in the use of the dial be omitted. For these it is right to expect the subscriber to pay. The same is true of regular manual practice, for if a subscriber calls for the wrong number and gets it, he is expected to pay for it.

Fig. 10 is a general view of a number of primary line switches. In the space above the switches indicated by the letter *M* the meters may be seen. These are in tight cases which are locked and accessible only to the official who has charge of meter reading.

Cash measured service is furnished by means of coin boxes attached to the line wires at the subscriber's stations. No coin is required to be deposited in order to call. When the called station answers, the reversal of current operates a magnet in the

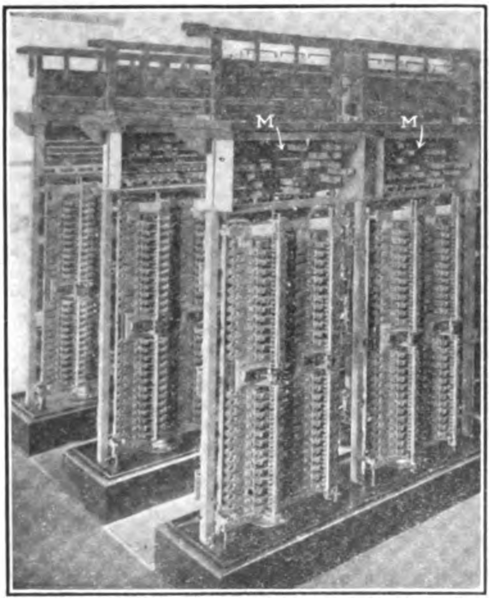


FIG. 10—Primary line switches with meters

coin box which short circuits the transmitter and places a shunt in parallel with the receiver. This prevents the transmission of speech, but allows the user to hear faintly the voice of the called subscriber. By dropping a coin in the chute, the shunts are removed, so that conversation can take place.

When a call is made to a free station as above described, no reversal of current takes place, so that the calling subscriber is not forced to make a payment.

6. *Private Branch Exchanges.* In both Oakland and San Francisco the nature of the business makes quite a large number

of private branch exchanges profitable to the subscriber and to the operating company. These boards are manually operated and have several trunks connecting them with the nearest public exchange office. Each business house is listed under one number in the directory. When a public subscriber selects the call number the connector switch must automatically select an idle trunk to the private branch board. This is done by a special type of switch known as the rotary connector. It responds to the impulses for the tens and units digits of the call number, but immediately thereafter acts as a selector until an idle trunk is found. These rotary connectors are grouped in hundreds so that in providing for this special service the call numbers are set aside in blocks of one hundred each. Thus in the Main office San Francisco, the 1100, 1200, 2100, 2200, 3100, 3200, 4100, and 4200 hundred units are set aside for private branch exchange service and no number in them assigned for individual lines.

Let us suppose that the call number of a certain wholesale house is C-4251 and that four trunks are required for the business. The connector switches in the 4200 group of the Main or C office will serve this board. These four trunks will be multipled to the first four sets of contacts in the fourth level of the connector banks, that is, corresponding to numbers 4251, 4252, 4253, and 5254. Contacts 4255 are connected to the busy tone so that if it happens that all trunks are occupied, the calling subscriber will receive the busy signal and be induced to release. The private contacts 4255 of the several connector switches are not multipled together. If while all four trunks are occupied, more than one called is received for the busy number, the second and later calls will also stop on 4255 and not be forced past to 4256 which might be assigned to other service.

If desired, the remaining four numbers in this same level, 4256, 4257, 4258, 4259 may be given to some other private branch board. In fact any grouping of the trunks of a level may be used, it being only necessary to reserve one set of contacts at the end of each group for busy indication.

The trunks to private branch board are treated exactly like subscriber's lines in the public exchange, each being wired to a line switch for calls to the automatic system. They terminate in jacks and signals on the manual private boards and can be used for establishing connections either to or from the subscriber. The operator is provided with a calling device which may be

switched by keys to any cord circuit. With this the operator calls into the automatic exchange and arrangements are made so that complete double supervision is secured on all calls.

In the case of a private branch exchange having sufficient magnitude of business to require it, the trunks leading from connector banks may be made one-way only and reserved for calls to the branch board. There will then be installed as many trunks from the latter to the public exchange as are necessary, these trunks being attached to line switches. The number of trunks is not limited by the number of contacts in a level of the connector bank.

7. *Transbay and Suburban Toll.* We come now to what is perhaps the most interesting feature of the combined telephone exchanges. On account of the relative positions of the two cities, and their close business and social relations, the matter of quick and satisfactory communication between them is of great importance.

The fact that a charge is made for all calls between the two cities makes it necessary to employ operators for putting up these connections, making records of the same.

Long distance toll work is necessarily handled in a different manner from suburban calls. In the former, the telephone company agrees to bring together two persons, in the latter merely two telephones. This is sometimes called the "two number basis" inasmuch as only the two numbers are recorded, no attention being paid to names.

A common method of handling suburban as well as long distance calls is to have each call received by a recording operator, who makes out a ticket. She tells the subscriber that he will be called when the line is ready. The ticket is then passed to a line operator, who calls the distant city and with the coöperation of a similar operator there, establishes the desired circuit. She then calls the station whose number was given by the person originating the call and allows the conversation to take place.

For the suburban work between San Francisco and Oakland it was thought best to abolish this slow procedure and use what is known as the "rapid fire" method. Accordingly provisions were made for allowing the recording operator at San Francisco, for example, to complete the call into the Oakland exchange by a calling device in San Francisco, and to allow the conversation to proceed at once. This virtually makes the recording operator a line operator and entirely dispenses with the services of a line operator to complete the connection in the distant office.

The recording operator is of course obliged to ask the subscriber who originates the call for his telephone number so that the cost of the toll service may be properly charged. It is to be expected that, either by accident or intention, wrong numbers will sometimes be given. To prevent error from this source a system of back checking has been devised, which will be described in detail later.

The operators are divided into two main groups, suburban and long distance. The latter are as usual made up of recording operators and line operators, each with the usual duties assigned.

The suburban operators work in pairs or threes and are termed suburban operators and checking operators. All calls for out of town come to the suburban operators, who act as distributors between the two boards. This is because of the relatively heavy nature of transbay and suburban service as compared to long distance service. The suburban operator puts up suburban connections while the checking operator verifies the correctness of the number given by the calling subscriber. Usually one checking operator verifies the work for two suburban operators, though during periods of light load the latter check for themselves.

The method adopted in making a call is as follows: The subscriber takes his receiver from the hook and calls the digit " 0 " on the dial. This lifts the wipers of a first selector to the top level and selects an idle trunk to the suburban board. Here a lamp attracts the attention of a suburban operator who answers the call by plugging into the jack and throwing the listening key on her cord circuit. She asks whether " suburban " or " long distance " is wanted. If the latter, she momentarily depresses the transfer key button associated with the trunk in use. This automatically transfers the call to the long distance recording board, where multiples of the incoming trunks appear. The proper operator, seeing the burning lamp, answers and cares for the call in the usual way.

If, however, the subscriber replies that he wants " Suburban ", the suburban operator asks him two questions.

" What number do you wish?"

" What is your number?"

This information she writes on a ticket together with the number of the incoming trunk over which the order was received. The pad of tickets bears the suburban operator's position number and is arranged to furnish duplicate copies. Having recorded the information she passes the duplicate ticket to the

checking operator who is seated directly in front of her. The two following operations are then performed simultaneously:

The suburban operator selects an idle outgoing trunk leading across the bay and calls the number in the distant exchange by means of her dial. The checking operator upon receiving the ticket plugs into the multiple of the incoming trunk shown thereon. Then by an independent set of apparatus she calls the number of the originating subscriber. If the checking operator finds that the number written on the duplicate ticket is wrong, she passes the ticket back to the suburban operator by dropping it in a special ticket box in plain view. The latter operator at once throws the cut-off key on the cord, thereby severing the connection from the outgoing transbay trunk. She then requests the calling subscriber to repeat his number. If he repeats the number previously given, she informs him that she can not reach him over that number. In most cases the subscriber now corrects his mistake by giving the true number. This is now entered on the tickets and the duplicate again passed to the checking operator for verification. Usually the suburban operator allows the connection to proceed, while the second check is being made, for, as a rule, the second number is found to be correct.

On the suburban operators cord circuit is provided two supervisory lamps which have the usual functions. The calling supervisory lamp burns till the subscriber in the distant office answers. Then the operator stamps the ticket in a calculagraph. At the end of the conversation both subscribers hang up the receivers. This lights both supervisory lamps. The operator then times the ticket and disconnects the circuits.

The completed circuit over which conversation is carried on is shown in simplified form in Fig. 10. It is balanced and quiet in service. The rapid break and make of the calling device in operating the switches through the cable under the bay causes no inconvenience to those using parallel trunks.

When a subscriber has secured connection with the suburban or toll board, it is necessary that he be permitted to signal the operator by moving his receiver hook up and down. This would ordinarily cause the release of his first selector since all automatic switches are arranged to be released by the depressing of the hook lever. To prevent this breaking of the connection a special arrangement is attached to the outgoing toll trunks from each office in place of the regular repeater. This enables

the release of the first selector used by the subscriber to be controlled by the operator.

After the subscriber has hung up, the operator pulls out her plug which automatically causes the release of the first selector.

8. *Toll Checking Apparatus.* In the preceding general description of the mode of operation, reference was made to the toll-checking operator and her apparatus. The general plan of checking is to connect to the incoming toll trunk in use a source of alternating current which produces a musical tone. By independent automatic switches the checking operator calls the number given. If correct she will obtain connection to the

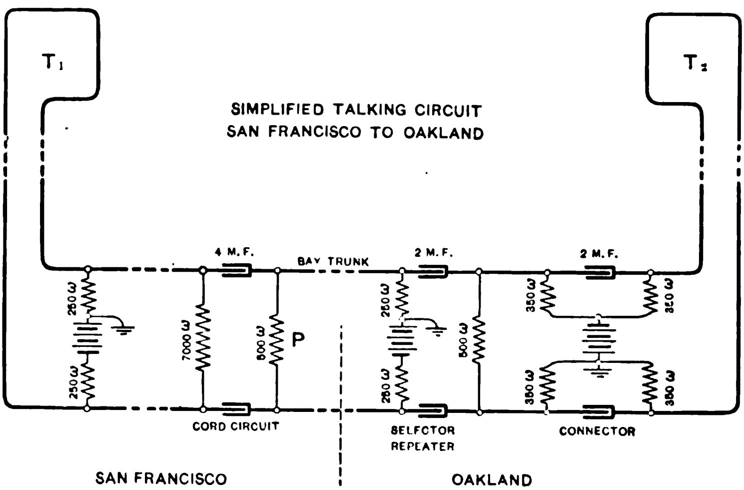


FIG. 11—Simplified transbay talking circuit

same line as that over which the call was received by the suburban operator, and by listening can hear the tone. The condition is shown in Fig. 11. The subscriber at the right has called the suburban operator over the incoming toll trunk. The operator has answered and made out the ticket. The checking operator has used a checking trunk to secure connection with the number given. At this point she presses the check tone key which connects to the incoming toll trunk a source of alternating current which produces a sound differing from the regular busy tone of the exchange. If the number is correct, the tone will be carried back over the toll trunk to the connector multiple and thence over the checking trunk to the checking operator.

The ordinary connector cannot be used by the checking operator in picking up the calling subscriber's line, because the latter is protected by a busy test which will not permit an ordinary connector to establish connection. For this work one check connector is provided in each hundred group. It is devoted exclusively to testing and checking. It is provided with three pairs of wires, one pair (*A* and *B*) for carrying the tone, another pair (+ and –) for operating the magnets for lifting and rotating the wipers and a third pair for auxiliary purposes.

The checking operator secures connection with the check connector in any hundred in any office by a system of first, second and third selectors which is entirely separate from the regular apparatus of the exchange. One first selector repeater is pro-

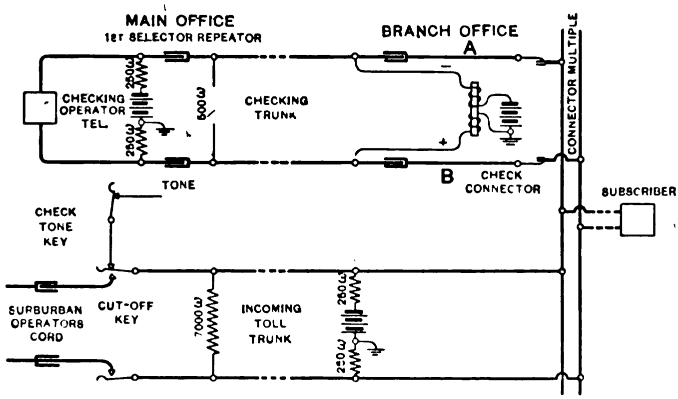


FIG. 12—Simplified toll checking circuit

vided for each checking operator, to enable her to select a trunk to any office in the exchange. In each office as many second selectors and third selectors are provided as are necessary for the work, the number varying in the different offices. These are operated by a calling device located at the checking operator's position.

When the checking operator plugs into a connection it lights a red lamp associated with the suburban operator's cord circuit. This shows that the checking operator has picked up the trunk. When the checking operator has verified the number and withdrawn her plug the red lamp is extinguished, thus notifying the suburban operator that the number has been checked and is correct.

As a guard, tending to prevent the checking of wrong trunks, the checking operator's cord circuit is provided with a lamp. This lamp will light when plugged in on a trunk which is waiting for the complet'on of a connection. If, however, the checking operator by mistake plugs in on a non-busy trunk, or one over which a connection has been completely established the lamp will not burn.

9. *Credit and Cash Tolls.* The larger proportion of the calls between the two cities are handled on the credit basis. From the records of the toll tickets, statements are made out at regular intervals and sent to the subscribers for payment. For such public places at which it is desirable to collect cash for suburban and long distance service, a regular coin box is attached to the

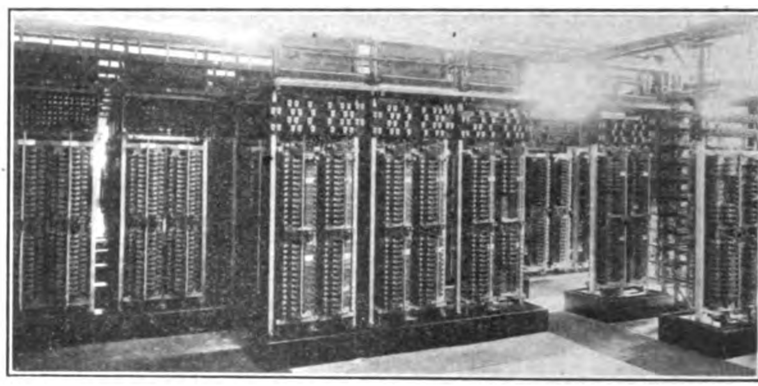


Fig. 13—Secondary line switches

telephone. The dropping of the coin gives a signal which reveals its denomination to the operator.

10. *Two Three-wire Operation.* In the general description of suburban toll operation a short reference was made to the trunk lines connecting the two cities. For the purpose of giving a better idea of the arrangement, a trunk line will be described which handles calls from San Francisco to Oakland.

The work of interconnecting the two exchanges was rendered more difficult by the fact that the Oakland apparatus is three-wire, while that of San Francisco is two-wire. The two-wire system requires only the opening and closing of the line circuit. The three-wire system requires each line wire to be grounded in a certain order. The San Francisco recording operator using

a two-wire calling device was required to operate three-wire selectors and connectors in Oakland, in some cases as far as thirteen miles away. This was done by means of repeaters which handle the impulses somewhat like a telegraph-repeater, except that it is necessary to transmit impulses only one way.

Each transbay trunk from San Francisco to Oakland ends in multiple jacks with visual busy signals on the San Francisco suburban board, and in a first selector-repeater in the Main office in Oakland. This switch is a first selector, to pick out trunks to the desired office in Oakland, combined with a repeater arrangement to convert the simple make and break of the two-wire system into the alternate grounding of vertical and rotary lines required by the three-wire system. The release of the connection as well as proper supervision is also provided in the repeater.

The operator is provided with a set of plugs and cords with which to connect incoming trunks from San Francisco subscribers to outgoing trunks to Oakland. A calling device is mounted on the keyboard and arranged to be switched into any cord circuit by keys. When a call comes in over an incoming trunk, it is answered by inserting the answering plug of a cord into the proper jack. An idle outgoing trunk to Oakland is selected by inspection of the visual busy signals, and the calling plug of the cord in use inserted into the jack. The calling device is then switched into the cord circuit and rotated in accordance with the desired number. This operates the switches in Oakland.

The supervision is accomplished as follows: Across each cord circuit of the suburban operator in San Francisco is bridged a polarized relay, *P*, Fig. 10. Normally the current from the first selector repeater in Oakland is in such a direction as to cause the relay to light its associated lamp. In the Oakland exchange the circuits from the first selector through to the connector are three-wire. When the called subscriber answers, it causes the rotary line to be switched from negative battery to ground or positive battery. This energizes a pair of relays in the first selector repeater which reverses the current supplied by the latter to the operator's cord circuit in San Francisco. This reversal causes the bridged polarized relay *P* to operate, extinguishing the supervisory lamp.

The release of the three-wire Oakland apparatus calls for the momentary simultaneous grounding of the vertical and rotary

lines. The two-wire first selector repeater at the Oakland end of the transbay trunk requires only the simple opening of its line circuit. By a suitable arrangement this is made to cause the release of the three-wire apparatus according to the manner just indicated.

The trunks from Oakland to San Francisco are operated straight two-wire, and hence are simpler than those just described. For the sake of securing sharper, better signals the trunks are wired through the first selector repeaters in the San Francisco main office. Supervision is secured by marginal relays.

A paper presented at the 249th meeting of the American Institute of Electrical Engineers, New York, May 17, 1910.

DUCTILE TUNGSTEN

BY W. D. COOLIDGE

When work was first started on the problem of producing a ductile form of tungsten, the metal looked very uncompromising. It was so hard that it could not be filed without detriment to the file, and was, at ordinary temperatures, very brittle.

It was of course known from the start that, at the operating temperature of a tungsten lamp, the metal was soft; but this fact seemed unavailing, for there was no tool that could be used for working the metal at such temperatures, and materials from which such tools could be made were lacking.

To a man ignorant of our success, the problem would certainly look more hopeless to-day than it did then. For since that time millions of tungsten filaments have been produced from all available tungsten ores, by widely differing methods, and by different groups of men. And each manufacturer has been fully alive to the fact that he must strive for the highest attainable purity. Yet all of the filaments made have been brittle. They are elastic and flexible as spun glass, but, like the latter, are incapable of taking the slightest permanent set.

Not only was there nothing in the past history of tungsten to encourage us, but, in the natural periodic system of the elements, the metal belonged to a family no member of which had been brought into a ductile state. The other members of the family are chromium, molybdenum, and uranium, elements which had always been characterized by hardness and brittleness. A study of the periodic system shows that, in a general way, elements of the same family do resemble one another in point of ductility, as well as in their other physical and chemical properties. For example, copper, silver, and gold are all in one family and are all very ductile.

Little encouragement could be drawn from the achievement of Dr. Von Bolton with tantalum, because of the fact that this element is in a different family. And the two families differ markedly in both physical and chemical characteristics.

The only arguments on which we could base the hope that tungsten could be produced in a ductile state, were founded on the effect of mechanical working and of chemical purity on the ductility of some of the other unrelated elements. But even this hope seemed of doubtful fulfilment, owing to the apparently insuperable difficulties of mechanically working this particular material.

Mechanical working increases the ductility of some metals. Cast zinc, for example, undergoes a marked increase in ductility when subjected to ordinary wire drawing processes. Some special steels, also, which, as cast, are coarsely crystalline, have to be handled very carefully until they have undergone a certain amount of mechanical reduction, while from this point on they are very ductile.

Chemical purity also, is, in general, conducive to ductility and in some instances, slight amounts of impurity produce a marked effect. Some striking examples of this are the following:

Copper is very sensitive to the presence of bismuth, even 0.02 per cent of the latter rendering it brittle when hot, and 0.05 per cent brittle when cold. Sulphur is also a harmful impurity, and copper containing 0.25 per cent of it is only moderately malleable.

Gold is rendered brittle by 0.05 per cent of lead, bismuth, or tin, and is no longer malleable when it contains as little as 0.0003 per cent of antimony.

Nickel is rendered unsuitable for rolling by the presence of 0.1 per cent of either arsenic or sulphur.

Platinum is made hard and brittle by 0.03 per cent of silicon. Its ductility is also considerably lessened by the presence of small quantities of the other platinum metals.

Tin is brittle when cast at a temperature either too high or too low.

The analogy with iron is in some ways more interesting than the above, for both tungsten and iron take up carbon, and may be greatly hardened thereby. And iron is extremely sensitive to traces of sulphur, phosphorus, and arsenic.

Our early experiments in mechanically working tungsten

led to work on tungsten alloys, and on suspensions of tungsten powder in metals in which there was little or no alloying. One of the most interesting suspending media proved to be an alloy of cadmium, bismuth, and mercury. This amalgam is very pliable. For our purpose it has several other important characteristics. Upon heating to about 140 deg. cent., it becomes soft and plastic, and from this point it retains its plasticity over a considerable temperature interval. While the amalgam is in this state, it is possible to incorporate with it considerable quantities of many foreign substances, such as tungsten, in powdered form. (Such a mixture, containing about 30 per cent by weight of tungsten was exhibited at the meeting.) At room temperature, it is about as hard as lead, but, at a temperature of about 110 deg. cent., it can be readily pressed through a diamond die, and comes out as a silvery looking strong pliable wire. If this wire could be freed from everything but tungsten and still preserve its present strength and ductility, it would solve the tungsten filament problem. But such is not the case. Upon heating it by the passage of current, in a non-oxidizing atmosphere, the mercury first distils out then the cadmium and then the bismuth. Some shrinkage takes place as the foreign metals leave the filament, and the remainder is brought about by raising the temperature to white heat. Most of the ductility of the wire leaves with the mercury, and the remainder goes with the cadmium. This finished filament has been used in thousands of lamps, but these all lack ductility.

The above experience was duplicated when we tried copper as a binding agent for the tungsten, and again when nickel was used for this purpose. In each case there was a ductile stage in which the filament could be bent and otherwise manipulated, but not a trace of this ductility remained after the removal of the foreign element.

The above experiments gave us several new and valuable methods for producing tungsten filaments of the usual quality. But in so far as our ultimate goal, a ductile tungsten filament, was concerned, they were not promising. They were, however, in one respect, instructive, for in the case of all of the above and with many other foreign additions, we got a complete removal of the foreign elements, at least so far as our analytical tests showed, with the final high temperature treatment of the filament. This seemed to indicate that we either did not need to worry about contamination from such elements, or else that

brittleness was due to traces of impurity so minute as to escape detection by our analytical methods.

To return now to the mechanical working of pure tungsten. This work received a great impetus by our discovery that an ordinary, dense, well sintered, tungsten filament can be easily bent and put into various forms, and otherwise manipulated at temperatures well below redness, and even below the temperature at which appreciable oxidation takes place. This helped us in two ways. First, it reduced the temperature at which mechanical working operations could be carried on, and, second, it gave a means of recognizing which of the mechanical and chemical processes involved in our experiments were bringing us nearer to the goal. Anything which reduced the temperature at which the metal could be permanently bent was, clearly, helping us.

We found that steps tending to the elimination of the last traces of certain impurities did greatly improve the resulting product. While it may be true that certain impurities present in small amount are harmless or even helpful, we know that certain other impurities are detrimental. We also found that a certain micrographic structure in the tungsten rod with which we start, was conducive to mechanical working and to ductility in the resulting product. Once arrived at the point where mechanical working was easy and where there was a certain amount of ductility in the product even when cold, the development became more rapid. It was aided by the construction of more refined apparatus, in the design of which care was taken to guard against the taking up of impurities during mechanical reduction processes, both from the atmosphere in which the work is carried on and from the surfaces of the tools.

Hand in hand with this improvement on the mechanical side has gone the work on greater chemical purity of the metal with which we start. One of the difficulties in purifying tungsten has been due to the fact, which has been pointed out by Smith and Exner and others, that tungstic acid is very prone to form difficultly separable complexes. Because of this tendency, especial care must be taken with regard to the purity of the reagents used, as otherwise recrystallization beyond a certain point does not result in corresponding purification.

The knowledge obtained from our various lines of research now makes it possible for us to prepare tungsten which can be mechanically worked without more difficulty than would naturally attend the manipulation of very fine wire.

The product which we now have is a perfectly pliable ductile wire, which has the strength of steel. (Specimens of ductile tungsten wire of various sizes were exhibited at the meeting.) It gives a lamp which is strong and whose filament retains its ductility throughout the life of the lamp.

The following data on the drawn wire, obtained from measurements made in the laboratory by Dr. Colin G. Fink, may be of interest:

Diameter (in inches)	Tensile strength (lb. per sq. in)	Specific gravity
0.150	——	19.30
0.005	490,000	——
0.0028	530,000	——
0.0015	600,000	20.19

The electrical resistivity at 25 deg. cent., expressed in microhms per centimeter cube, is, for the hard drawn wire, 6.2, and for the same annealed, 5.0.

The temperature coefficient of electrical resistivity between 0 deg. and 170 deg. cent is 0.0051 per degree centigrade.

The above values, with the possible exception of the temperature coefficient, are of course somewhat dependent on the early history of the wire from which they were determined.

The work which has been outlined above is the result of the close coöperation of about 20 trained research chemists, with a large body of assistants, in the research laboratory. These men were of course given, from the factory organization, all of the mechanical and electrical assistance they could use, and were assisted in no small measure by the staff of the incandescent lamp factory.

NOTE

The following paper is to be read at the 27th Annual Convention of the American Institute of Electrical Engineers in **Jefferson, N. H., June 27—30, 1910.** This paper is to be presented under the auspices of the Electric Lighting Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

Written contributions will be read at the meeting, time permitting, for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the paper in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion by mail.

Contributions to the discussion of this paper should be mailed to **William L. Robb, Chairman Electric Lighting Committee, P. O. Box 592, Troy, N. Y.,** so that they will be received not later than June 23, 1910. Written contributions arriving within 30 days thereafter will be treated as if presented at the meeting

A paper to be presented at the 27th Annual Convention of the American Institute of Electrical Engineers, Jefferson, N. H., June 27–30, 1910.

THE MODERN OIL SWITCH WITH SPECIAL REFERENCE TO SYSTEMS OF MODERATE VOLTAGE AND LARGE AMPERE CAPACITY

BY A. R. CHEYNEY

The oil switch has become a fundamental part of all large generating systems, and so well has it fulfilled its function that not only has it superseded practically all other forms of switches for such service at all voltages, but manufacturers unhesitatingly claim that it can be constructed so as to safely open short circuits under the worst possible conditions in systems of unlimited kilowatt capacities, the only limiting condition, of course, being that the consumer be willing to pay for it.

In spite of this assurance, repeated warnings that the present switches are becoming a source of possible danger in the rapidly growing central station systems of our large cities are being heard, although neither manufacturer nor operator has seemingly thus far placed any absolute safety limit on just how large a system the present switch is entirely capable of protecting.

Switches may be divided into three classes, each class being further sub-divided into extra high voltage, moderate voltage and low voltage. The three main classes are based upon the maximum generating capacity that the switch may reasonably be called upon to interrupt. The classification, therefore, becomes in fact switches for small systems, for systems of moderate capacity, and switches for use in systems of the largest size. So long as the operating man does not object, the rating of this latter type of switch will continue to be for systems of "unlimited capacity," as any experimental evidence to the contrary is at the expense of the operating system itself.

It is further manifest that oil switches may be built to safely

and continuously carry any current that may be required. The use of the switch as a circuit-breaker is the limiting factor in the case. Every switch thus used must not only be able to safely carry or interrupt the load of its particular section, but it must also be capable of safely and repeatedly interrupting short-circuits under severe conditions, with the whole capacity of the generating, transmission, and receiving systems behind it.

The switch with which this paper is mostly concerned is the type almost universally used in the large generating systems of our cities, where the voltage usually runs from 13,000 to 6,000 volts per phase, and is manufactured in various sizes, the 2,500-volt switch with a capacity up to about 3,000 amperes, the 15,000-volt switch up to 2,000 amperes, and the 35,000-volt switch up to 300 amperes rated capacity. Under these conditions the temperature rise in the oil cylinders or tanks is generally kept as low as possible, 28 deg. cent. being sometimes specified.

The switch of both large and small ampere capacity for extra high potential systems seems to have rapidly made a place for itself in the high-tension transmission systems of the country, and to have been extremely satisfactory in most instances. One 60,000-volt switch, it is claimed, opened twenty-five consecutive short-circuits, with a generating capacity of 10,000 kilowatts, within a space of one-half hour, and although the oil was carbonized to a considerable extent, the switch opened the arc entirely satisfactorily on the last break. In another instance two 60,000-volt breakers which had been in service for three years have opened several hundred short-circuits, many of them severe, without a change of oil. The generous dimensions of these switches are sufficient to show that the design is amply safe with regard to distances between conductors, the manufacturers claiming that they figure on an oil which has dropped in insulation until it may be broken down from 6,000 to 10,000 volts on a 0.2-in. gap between needle points. It is impossible in practice, with systems of this nature, to maintain the oil at an exceedingly high insulating value without a great deal of labor and inconvenience, particularly on account of the moisture that is absorbed from the atmosphere. In these switches for high voltage systems, which are now on the market in capacities up to 400 amperes at 110,000 volts, experience seems to show that a large volume of oil greatly increases the factor of safety. Some manufacturers also claim that in switches of this class a horizontal is superior to a vertical break as the pressure due to the head of

the oil above the contacts is more effective in preventing the arc from reaching any large dimensions. Switches with a horizontal break are usually made with a thin knife blade in order that it may cut through the oil with the least disturbance. Judging from the written expressions of the users of these high-tension switches, it is evident that for the conditions under which these switches operate they are giving very satisfactory service.

Until the introduction of the steam turbine with its high rotative speeds and correspondingly low self-induction, the present plunger type of switch seemed to fulfill every expectation in moderate voltage systems of large generating capacity. The enormous growth of connected load and, at the same time, the adoption of the turbine as a prime mover, have brought about conditions unforeseen; and not only has the ability of modern switch construction to safely care for the new conditions been questioned, but experimental evidence would lead to the conclusion that either a new form of switch is urgently needed or else a marked change in switchboard construction and station operation.

The high-power switch for 6,000- to 13,000-volt service has at all times required careful supervision, constant attention to smaller details of its operating mechanism, and periodic tests, in order to ascertain that it was always ready for service. This, of course, is not unreasonable. Heavy short-circuits, however, have frequently demonstrated the fact at the present time in our large stations no circuit-breaker which has once opened under heavy short-circuit conditions is entirely safe to be put back on the line again without a thorough overhauling of contacts, cleaning up of the switch and its compartments, on account of the large amount of oil which has been blown out by the explosive pressure of the arc, and also the refilling of the switch cylinders. It is frequently necessary to insert an entirely new set of contacts and to file down the rod tips. This whole operation involves a period of at least two hours, and if spare feeders are not available may lead to considerable annoyance, while, in any case, it may involve a temporary disablement of a large and important investment in apparatus.

Changes, such as the substitution of steel for brass pots, the addition in some instances of insulating dashers to assist in keeping the oil within the pot and also to facilitate the breaking of an arc, and improved operating mechanism and contacts, cover practically all the main points that have been improved

upon, since the introduction of the 8-in. cylinder eight or ten years ago, notwithstanding the enormous increase in maximum short-circuit output of the turbo-generator over that of the engine-driven alternator of equal capacity and the fact that the size of units has increased from 5,000 kw. to 20,000 kw. The substitution of boiler-iron tanks for wooden tanks and the gravity opening, with a means of obtaining a certain forced oil flow across the contacts on opening the switch, are a few of the changes in another type.

The Committee on High Potential Disturbances of the Association of Edison Illuminating Companies, 1909, notes that several of the larger companies are making use of reactances in connection with their turbines. These are installed either in the neutral leads of the turbo-generator or in the phase leads themselves. The reactances also facilitate parallel operation. A committee of the same body during the previous year suggested a limit of 40,000 kilowatts of installed machinery as a maximum generating installation that could be safely protected by a modern switch. As, in several instances, the switch has caused considerable damage, frank discussion in the line of improvement of the switch design is asked for.

As a matter of record, with 15,000 kw. of turbines in service, the latest type of oil switch has been quite recently practically emptied of its oil, the remaining oil being reduced to a state of absolute blackness and the contacts and rods so badly burned that they were unfit for further use without renewing, makes it evident that some change is needed in our present switchboard or switch design.

Modern operation generally calls for the use of a single operating bus-bar for reasons of both reliability and economy. Choke coils to limit the generating capacity in one section of the bus to a value of perhaps 20,000 kw., or a capacity slightly above that quoted when the switch was disabled, would seem hardly practical. As the load continues to grow with enormous strides, it would certainly seem that a more powerful type of switch should be found. As far as ascertained, resonance rises of potential due to the opening of an arc in an oil switch are of comparatively rare occurrence. It is natural to suppose that, whatever changes are made, the arc will still be broken under oil.

A few remarks of a general nature on switchboard construction and arrangement may not be out of place. A feeder switch, or

circuit-breaker includes properly the knife switches separating the switch from the underground cable system, the series transformers, relays, control wiring and the switch itself with its fireproof compartment. It would not, therefore, seem illogical to adopt a type of construction in which all of these parts are relatively close together, instead of being scattered perhaps hundreds of feet apart as is frequently the case. For instance, the series transformer; the relays, the current through the coils of which, incidentally, should also pass through the circuit ammeters of the operating board, and the actuating mechanism of the switch belong together. The cable knife switch should be so placed as to be visible when working on the circuit breaking switch itself—in other words, in the base of the switch compartment. The bus bar knife switch should also be visible to any one working on the selector switches to obviate any chance of mistake in switching, and, furthermore, to protect the operator. This means, then, the bus bar and selector switch compartments must be one, so constructed that every switch section is independent and that the complete demolishing of one switch will not in any way affect either the neighboring switches or the bus bars themselves. This arrangement, mentioned above, will not only greatly reduce the space required for present switchboards, but will assist materially in proper maintenance and repair.

It is possible that it may become good practice where the plant equipment includes two switches in series for each feeder—one automatic and the other non-automatic—to allow the time element relay to open both switches in order to assist in breaking the arc, although this should not be necessary with a reliable switch. In connection with the use of choke coils the suggestion has been made that these coils be short-circuited by a heavy switch which would be opened by a relay when required. It is doubtful if any switch yet constructed would be quick enough to give the effect desired and on this account, and also on account of simplicity, choke coils, if installed at all, should be so designed as to care for operating conditions without the intervention of an iron core or moving mechanism.

As an illustration of the exceedingly heavy duty required even of a 300-ampere switch on a single feeder cable in the case of a 50.000-kw. steam turbine station of 6,000 volts, the instantaneous short-circuit current would amount to $50.000/\sqrt{3}\,E \times 50 = 240{,}600$ amperes per phase, or a kilowatt output, assuming a power factor for the short circuit of 40 per cent, of $50{,}000 \times 50 \times 0.40 = 1{,}000{,}000$ kw.

A 100,000-kw. plant under similar conditions would give an output of 2,000,000 kw. It is expecting a great deal of a 300-ampere switch to suppose that it could be safely figured on to care for such an enormous amount of energy. Yet the facts remain as stated. There are several modifying conditions, however, which enter into the problem. In the first place, short-circuits as a rule are not absolute short-circuits, and in this way the number of amperes actually interrupted is probably far less than that calculated. It must also be borne in mind that even if a circuit-breaker on a feeder were provided with an instantaneous relay, the time element of the switch itself is considerable, so that by the time the arc had been opened, the armature reaction of the machines would have, to a certain extent, become effective, thereby dropping the voltage and still further lowering the amperes at the break. If the safety of the switch alone is considered, it would doubtless be expedient to install inverse time element relays in connection with the feeders which would give an exceedingly long time interval in connection with the 100 per cent or more overload setting of the breaker, in order that they might give perhaps a three or four second interval between the occurrence of the short circuit and the opening of the switch. While specific information with regard to the length of time which is required for the armature reaction of alternators to become effective is lacking, there is no doubt that a mean might be drawn between conditions most favorable to the switch and those upon which depend the stability of operation of the main and substation synchronous machinery. Were it not for the possible rise in potential due to the breaking of the arc when the current is perhaps at a maximum instead of at zero point of the wave—which is another fact upon which further light is much needed and upon which the oscillograph without doubt will prove of great assistance in effecting a solution—the operating man would much prefer to have a short circuited cable cut off instantly before the trouble has had time to reach its heaviest proportions or has become severe enough to interfere with the frequency or voltage of the system.

The problem of the oil switch demands the more nearly exact solution of these questions. The protection which might possibly be afforded against the effect of static surges by the aluminum cell arrester might well be considered in this connection. With this protection, it would seem that the advantage lies practically altogether in favor of opening the switch itself

as quickly as possible, by which it is understood that the greatest reasonable amount of time should be given by means of the relay to the switch before the latter starts to open the arc without, on the other hand, taking chances of throwing off the synchronous machinery. Under the best of conditions, however, we can but see that the switch is a relatively weak link in a system involving millions of invested capital.

The breaking of a circuit consists of inserting more or less gradually into the circuit a resistance which grows at a variable rate from zero to a maximum. At the moment the switch is leaving the contact, the greater the $C^2 R$ loss in heating, and especially if the circuit be inductive, the greater the amount of arcing. The rapid falling off in amperes as the resistance is increased by distance, when a considerable amount of metal is vaporized, and by this means the breaking of the arc is considerably hindered, is probably not at first accompanied by any great drop in the heating effect on the oil and the contacts, the $C^2 R$ loss for a certain length of time being perhaps practically constant. This, in part, is probably the cause of the explosive pressure set up in the cylinder by the oil vapor assisted by the actual displacement of oil by the arc itself. The prolonged arcing is evidently also the cause of the large amount of carbonization which takes place on opening a heavy short-circuit under oil with the modern switch.

Although there has not been a great deal written upon the exact nature of what takes place when a heavy arc is thus broken, experimental evidence has shown us that the quality of the switch oil will without doubt play a very important part in the switch of the future. The electrostatic stress set up between two charged conductors in a light mineral oil such as is used in switches and transformers, will, under proper conditions, even though no appreciable current is allowed to flow, release considerable quantities of gas without appreciable change in the oil itself, and as this gas is naturally rich in hydrogen, may it not be that the explosive violence of some of our short circuits is due to the combination of this gas and the gas driven off by the heat of the arc with oxygen, possibly of the air? The carbonization which takes place when a heavy short-circuit is broken is sometimes sufficient to make a deposit on settling of $\frac{3}{8}$ of an inch in a 4-inch column of oil, or a total volumetric proportion of 10 per cent between the amorphous carbon and the clear oil above. The actual sample measured was taken from

an oil switch cylinder from which two-thirds of the oil was blown out by the violence of the explosion. The physical analysis of the fresh oil (No. 6 transil oil) was as follows:

Flash	353 deg. fahr.
Burn	402 " "
Gravity at 60 deg. fahr	31.4 B.

As regard acidity, the oil was very nearly neutral, 0.09 per cent of potassium hydrate being required to neutralize same. There was no organic matter present. Various tests were made to ascertain the specific resistance and the dielectric strength of the above oil under the following conditions; first, the new oil; second, the blackened oil as taken from the switch; third, the clear oil after filtering off the carbonization. Careful tests were made under different conditions such as the sparking distance between needle points, between flat disks, between two ¾-in. balls, between a needle point and a disk, between a needle point and ball, etc. In some of the tests it seemed that the filtered oil after heavy carbonization showed an increase in specific resistance over the new oil. The dielectric strength also seemed materially increased after carbonization and filtering. The carbonized oil as taken from the switch showed a specific resistance of only one-fourth that of the new oil or of only one-eighth the resistance per cu. cm. of the oil after removing the carbonized particles by filtration, although another series of tests of other samples of the same oils failed to confirm the above figures; still there was a marked difference between the samples, although any increase in specific resistance or in dielectric strength failed to materialize except in one instance. The following figures, however, which are abstracted from the second series of tests represent the sparking distance between two ¾-in. balls at approximately 22.5 deg. cent. under a depth of oil of 2¼ in.

Sample	Gap	Volts
No. 1—Blackened oil (filtered)	0.15″	12,000
	0.20″	29,000
No. 2—New oil	0.15″	12,000
	0.20″	29,500

The following figures, representing the break-down point in inches at 30,000 volts pressure, as measured by an electrostatic voltmeter, checked by needle points, are also given:

Sample	Needle points	Needle and ¾-in. disk	¾-in. Ball and ¾-in. disk	Between ¾-in. balls
	in.	in.	in.	in.
No. 1—Blackened oil......	0.635	0.610	0.320	0.220
Blackened oil filtered........	0.530	0.750	0.250	0.190
No. 2—Blackened oil......	0.420	0.675	0.615	0.310
Blackened oil filtered........	0.300	0.600	0.290	0.185
No. 3—New oil...........	0.575	0.755	0.502	0.665

Temperatures in the above table all 26.5 degrees C.

All distances were measured by michrometer, the voltage adjustment being secured by finely adjusted resistances in the primary of a 40,000-volt testing transformer. As this may have introduced possible error due to change in wave form the figures are given as being perhaps at best, only approximately correct.*

Whether or not the changes in an oil produced by carbonization under heavy arcing improves or reduces the values of the remaining filtered oil for use in oil switches, it seems quite urgent that oil for switch purposes be chosen with great care, and manufacturers should make public satisfactory specifications to cover such oils and the testing of the same. It is by no means certain, as is frequently claimed, that a good transformer oil will make a good switch oil. Carbonization under heavy arcing is undeniably unavoidable. The study, however, of the physical and chemical nature of the actual conditions existing while the arc is being drawn through the oil with regard to the oil itself may lead to valuable conclusions that will somewhat strengthen the present oil switch situation.

It may be necessary to reduce the carbon content of the oil or possibly the hydrogen and more volatile components, even perhaps at the expense of changing the viscosity. Careful specifications will be welcomed by operating companies.

The severity of the arcing is naturally dependent upon the pressure of the oil surrounding the arc, the temperature of the

* Other interesting figures in connection with the same kind of investigation are given in a paper read before the Manchester Local Section of the Institution of Electrical Engineers, by W. Pollard Digby, and D. B. Mellis, of which an abstract appears in the London Electrician, April 1, 1910. Important papers on this subject by Messrs. Skinner, Kintner, Steinmetz and others have appeared in the technical press.

oil and contacts, the velocity of switch opening, and, of course, by the ampere density at the point of break. The amount of vaporization of the contacts should be reduced to a minimum by properly proportioning the switch parts, by artificial circulation of the oil across the contacts as they are separated, and by increasing the velocity at the break to as high a degree as is possible. Severe arcing, even under oil, may without doubt be sufficient to set up heavy oscillations in a large underground system and, although much has been written upon the advisability of retarding the switch in its action, it frequently seems very advisable to have an absolute short-circuit broken as quickly as the switch will open it, the limiting factor being the reliability of the switch itself.

The oscillograph in the near future will also doubtless add to our knowledge of the conditions existing in a severe arc closely confined, as in the case of an oil-switch cylinder under pressure. As stated above there seems to be considerable difference in opinion among engineers with regard to whether the opening of a switch should be in a horizontal or vertical direction. While many of the high-tension switches in the West use a horizontal break, depending upon a large volume of oil and a narrow knife blade for contacts, practically all of the high-power switches of moderate voltage have a vertical throw, in some cases opening by gravity, which has the advantage that the switch can never accidentally fall into contact; while in other types the switch opens upwards.

There has been developed, although apparently it has never yet been introduced as a commercial article, an oil-switch in which the oil is at all times under pressure which is maintained by a compressed air system—a pressure line of perhaps 150 or 200 lb. caring for a number of switches, and a gravity or return line returning the discharged oil to the system. This principle seems to be exceedingly promising insofar as breaking the arc is concerned, the switch cylinders being either always full of oil under pressure, the opening of the contacts allowing a heavy stream of oil to be forced directly across the arc and through the hollow contact to atmospheric pressure, or as in another case, where the tripping coil opens an oil valve which admits large quantities of fresh oil under pressure to come into direct contact with the heated terminal directly at the base of the arc. It is undeniable that the mechanical squeezing out of the arc is what we need.

The forcing of considerable streams of cooled fresh oil across the contact face to the atmosphere, thereby eliminating all carbonization and gasification from the oil switch itself, gives a pleasing prospect of what the future may have in store. The breaking of a heavy arc by the weight of a nine- or ten-inch column of oil, especially in small or confined areas is going to be somewhat of a doubtful matter especially as the sizes of operating systems increase.

Another matter which should be carefully considered in connection with the vertical cylinder oil switch is the magnetic repulsion between the oil switch cylinders at times of heavy short circuits. Insulator bases are required, of great mechanical strength, to safely withstand this unusual strain which is perhaps similar in its nature to that which causes the opening of high tension switches under similar conditions, and it may be perhaps that broken base insulators may be traced partly to this cause.

In the matter of oil-switch contacts, practically every form imaginable has been tried particularly in the smaller switches. It need only be mentioned, therefore, that there seems a strong tendency to rely upon the cooling effect of the oil and the large radiating surface of the pot or oil tank to carry off the heat from contacts which in air would run exceedingly warm. An oil switch contact should on account of the very nature of the insulating medium be of at least as large proportions as a similar current carrying contact for use in the air; especially so since carbonization, sedimentation, moisture and other causes may interfere with the contact; and, above all, because it is practically out of sight at all times.

Switches of the more powerful types are generally sufficiently provided as to contact area, but there are certain switches of high current carrying capacity designed for mounting on marble switchboards, for hand or solenoid operation in which the contact surface is naturally too small. The switch, including the oil and the oil tank itself, run exceedingly warm with the contacts most carefully adjusted. This seems a mistake and should never exist in any oil-switch which is placed in a position of responsibility. The temperature of such a switch contact cannot be noticed by handling as can that of a low tension knife switch, so that the greater amount of power per ampere precludes any cutting down of contact area if at the expense of a rise in temperature over normal conditions. Information as to the increase of conductivity of a contact due to increase of pressure is not very plentiful for contacts under oil.

The operating mechanism of large oil-switches can be of the pneumatic, hydraulic, solenoid or motor type. The pneumatic control seems especially adapted for switches of extra high voltage and of certain types, although these switches are very frequently solenoid operated. In the switches of systems of large ampere capacity, the choice between solenoid and motor types of mechanism seems an open one. Both types are fulfilling their proper functions in a satisfactory manner, so far as can be ascertained.

The method of control and the wiring of the same vary with conditions. Generally, the pilot switch that stands in the "off" position and inclining toward the contact last in use is adopted, principally for reasons of wiring connection. The style of pilot switch which remains in contact until thrown into another position is a most excellent switch, and for some reasons, especially in synchronizing, is preferable to the open type, if connections allow of its use. Certain switchboard designers prefer the pull-button switch where all the contacts are on the under side of the operating table, thus precluding any possible switch action due to the dropping of any conducting body upon the operating table, and thus operating switches at inopportune times.

Generally, the simplest switch seems the best, and with a switchboard comprised of plain knife switches so that the operator can always see that his contact conditions are satisfactory, the limit of simplicity has been approached. Synchronizing by pulling out a switch seems perhaps the least bit awkward as contrasted with throwing it in. Not only is it advisable as stated below that the circuit ammeters shall indicate any open circuit condition of the relay coils, but it is advisable if possible that the control wiring be so installed that the operator is informed by his pilot lamps in case of any failure or open-circuit condition in actuating current supply through the relay or the pilot switch itself.

Standardization in the case of oil switches has been made somewhat difficult, so that an excessive number of spare parts must at times be kept in stock. It seems unfortunate that several types of motors, for instance, all of the same general size, speed, and voltage shall be necessary, frequently perhaps on account of the changes of the distance between shaft center and base or a slight change in the base clamping arrangement. The same, of course, applies to motors on governors, main field

rheostats, field-break switches, etc. In laying out a new station the designer should see that the number of types of auxiliary motors are reduced to a minimum, so that instead of six or eight or even more types, two or three will fulfill the conditions.

The interlocking of high power switches has not generally seemed advisable up to the present date excepting through the control wiring scheme. It is, of course, always advisable that this be so arranged that the synchronizing plug or switch shall carry the actuating current of the selector oil-switch so that it will be impossible for the operator to synchronize a machine with one operating bus and throw it on the other. Interlocking is furthermore undesirable in many instances as the buses are frequently doubled up for various operating reasons, this arrangement affording a very flexible means of caring for the every day happenings of the central station system. In a system in which each generator and feeder consists of a main circuit-breaker and two selector switches any set of selector switches may be utilized for tying together the buses, although the generator switches will generally be used.

Interlocking in the smaller types of switches designed for mounting directly on a switchboard panel or otherwise has not as a rule seemed advisable. The great tendency toward cheapness of production has actually interfered with proper design of some of the smaller switches to such an extent that it is suggested that all unnecessary complications should be avoided and the money invested placed in the switch itself, providing only a first class yet simple operating mechanism. The smaller type of switch may be hand—solenoid—or motor-operated. When used as a circuit-breaker it must be installed in systems within the limits of capacity as given by the manufacturers. Its use on systems of the heavier class is not advisable unless in substation installations when it may be safely used as a single throw device for a bus selector switch, provided that a heavy type of switch is used as a circuit breaker. This lighter switch finds a very abundant field on account of its relatively low cost, especially on voltages from 2,400 to 13,000. It is frequently used as a remote control switch, as a manhole or pole-type switch, and on the outgoing 2,400-volt wires from alternating-current transformer substations. There is lacking, up to the present time, any adequate time element device for this useful switch, so that unless special relays are used on the switchboard, circuit-breaker setting by means of the tripping coils generally means the opening

of every switch in the series on short circuit, which is extremely objectionable. The usual practice, therefore, in this connection, is to solidly block everything possible and to remove all blocks only at the time of known danger or when switching. This at best is a dangerous practice and it is hoped that at a near date some satisfactory time element device will be furnished with all such switches for station use, as this will not only make possible selective setting of the various switches, but will possibly protect the switch itself.

In the alternating-current substations of a generating system of any considerable size the double throw form of polyphase switch in which both of the main bus bars, for instance, of the substation enter one switch, is generally inadvisable, especially in the switches of large ampere capacity and one self-contained oil tank such as is being furnished at the present day. It is preferable to install two first class oil switches, one for each bus in such a situation that repairs to switches and regular overhauling can be carried on safely and all chances of trouble between buses, and also the necessity of lowering an oil tank with very small clearances while the switch is alive, is practically entirely done away with. This double-throw type of oil-switch in which the dimensions are reduced to a minimum and the design is influenced to a large extent by commercial conditions, is especially dangerous if used as a circuit breaker. The operating mechanism, furthermore, of many of the switches of this type is very frequently of too light a nature to be consistent with the responsibility thrown upon the switch. Further defects which are brought about by the necessity for economy of space in the same type are weak insulators, and weak insulator support, also the difficulty of aligning the contacts and the contact yoke and of keeping them in proper alignment. Loose insulators, loose studs, and leaking tanks are of very frequent occurrence with some types of switches.

If light duty switches are installed in situations where they can be called upon to open short-circuits beyond their rated capacity in kilowatts, the oil is badly carbonized, the tanks are liable to become damaged, the contacts burned excessively, and the switch emptied of its oil if not actually short circuited. The oil tank for these light duty switches should be given an ample margin of security and purchasers of switches, particularly those which are to be used on systems of large size even though they are not to open exceedingly heavy arcs should

specify tanks of heavy sheet metal properly riveted and absolutely oil tight. A great deal of trouble has been experienced through leaking of switch tanks in which, mainly for reasons of cost, the weight of the metal has been reduced until the tank itself is much inferior to that of several years ago. A one-eighth inch boiler plate tank, properly riveted is superior in every way to the light weight tanks now so well known. These latter remarks apply particularly to switches for use on switchboard panels. There are certain occasions when commercial conditions step in and a switch is desired at a minimum of cost, even at the expense of a certain degree of security. The operating switchboard of any main or substation, however, is not a location where security can in any way be dispensed with.

There is urgently needed a new type of oil-switch of the cheapest form, preferably of the single-pole type, which shall be automatic in case of predetermined overloads, and which shall be capable of being installed in place of present line boxes on overhead 2,400-volt distribution lines. There is a wide field for the introduction of just the right switch in this connection. At the present time, the market offers no satisfactory device. As these switches could be made in enormous numbers and as the design may be made so that the factor of safety excepting only the matter of insulation, is not exceedingly high, it would seem that it should be possible to manufacture at wholesale such a device that would in a measure compete, even in cost, with the present enclosed fuses and line or manhole cut-outs.

Experience has demonstrated that constant vigilance is necessary with regard to every part of a generating system if service conditions are to be maintained at the highest point of reliability. Especially so is this true of the oil-switch in large systems. Certain defects can be noticed by visual inspection; others require the operation of the switch one or more times, while the inspector closely watches the mechanism and tanks. Still others can only be found by actually taking the switch apart and reassembling it. The inspection necessary, therefore, covers the knife switches, the insulators and contacts, oil-switch mechanism, tanks, rods, base insulators and compartment. To best accomplish this, the work of switch inspection may be sub-divided as follows:

1. Daily inspection of mechanism, tightening up of possible loose nuts, etc., general cleaning of switch. This covers all that can be observed with a reasonable amount of attention while the

switch is in service, and is given every switch whether carrying current or " dead."

2. Weekly inspection, covering the operation of the switch from four to six times to observe clutch conditions, tripping coils or contacts, open-circuits in wiring, loose parts, bolts, nuts, etc. This test also insures the switch being securely bolted down to its compartment. All doors are taken off or swung open, and tanks, rods, yokes, etc., examined leaky oil tanks cleaned up and any dirty base insulators cleaned off. This latter inspection has frequently located broken base insulators, insulators loose in their iron mountings, loose bolts securing base insulators, loose yokes and wooden shafts, and on one occasion a yoke and set of rods which had actually become disengaged from its clamp on the vertical wooden rod and fallen into the closed position, thereby closing one phase of the switch absolutely without the operators' knowledge. Defective alignment of cylinders, particularly in the case of the older type of switches, and improper switch action are also thus located. This inspection also locates leaky oil tanks, defective cable connections and terminal insulation.

3. Once a year every switch is completely taken down, each part cleaned and oiled, contacts brightened, supplied with fresh oil, and any minor defects that may have crept in are remedied as far as possible.

These three inspections have been found to cover fairly well the operation of the oil-switch in service. The whole of the work outside of the inspection itself is cared for by one man, excepting that the annual overhauling makes it necessary to add one helper to the force. This is in a plant of some 90 high-power switches.

The yearly inspection has discovered at times defects of a very serious nature which would not have otherwise been located, excepting through the failure of the switch mechanism to operate in service, and also troubles with the switch cylinders, rods or contacts. It is desirable that this systematic inspection be recorded, a separate card being used for every switch on which the various defects are noted. The main purpose, however, as stated above, is that the switches may be in working condition at all times both as to mechanism and the switch itself. Failures to operate when called for, defective contacts, low or defective oil, loose parts within cylinders, defective rod tips, or broken insulators may, any one of them be

the means at a most inconvenient time of causing trouble. Further records of switch condition besides the details given from the above cards are obtained by grouping the various defects in order that the weak points of the switch may constantly be kept in mind. The number of times the switch is thrown under inspection exceeds in all probability the times that it is actually used in service and has a tendency to cause a certain amount of switch trouble itself by loosening the bolts and contacts.

Type H Switch Record—1909

Minor adjustments not noted

	In service	Weekly test	Yearly overhaul	Total
Failed to open	0	0	0	0
Failed to close	6	10	0	16
Pumped	0	5	13	18
Oil renewals	7	0	81	88
Oil thrown on short-circuit	7	0	0	7
Contacts renewed	7	0	13	20
Base insulator loose or broken	0	19	9	28
Failure to open short-circuit	0	0	0	0
Defective contact at brushes	0	0	12	12
Broken castings, bearings, etc	0	0	5	5
Bent crank shafts	0	0	1	1
Clutch, trip coil and control finger troubles	0	35	2	37
Friction in mechanism	0	0	27	27
Troubles with compartments	0	0	2	2
Closed accidentally	0	0	0	0
Opened accidentally	0	0	0	0
Switches operated, times				35,000
Short-circuits opened	12	0	0	12

It, however, is the only means available whereby the switch action may be entirely depended upon.

The daily inspection thus eliminates the minor troubles apparent to a trained observer; the weekly inspection makes it possible to practically eliminate all external troubles in the switch compartments and in the mechanism, and especially failures to operate when called upon, whether due to open tripping coils, defective clutch coils or otherwise, and practically insures the switch against trouble due to pumping; while the

yearly inspection cleans up the switch as a whole, making it possible to start a new year with switches fresh and complete from top to bottom.

The actual expense for material in switch maintenance is probably equal to the labor item. The results obtained in a year's service, including operation and inspection of some 90 switches, subdivided into trouble of the mechanism and those of the switch proper are shown in the foregoing table.

In conclusion it may be briefly stated that the present state of oil-switch development, particularly described above, with especial regard to its continued use in the large installations of the future, has not given the operating man quite the same vision of perfect security and unlimited capacity as he would desire. A more powerful switch is seriously needed, a switch which will stand up in continuous service for at least a year without the necessity for overhauling every time a short-circuit is opened. It would not seem unreasonable to wish for this condition in any piece of machinery; and without doubt the oil-switch will be brought up to the standard desired when the operating companies and the manufacturers get sufficiently close together. The use of oil in the future switch seems assured. The problem is the right way to use it. From the standpoint of the present enormous and growing investments that are being protected by the device, and with a clear knowledge of the result of failure, there is no doubt that between the designer and the user and with perhaps the assistance of the physicist and chemist that the problem will be readily solved, when once its real importance is fully comprehended.

DISCUSSION ON "THE APPLICABILITY OF ELECTRICAL POWER TO INDUSTRIAL ESTABLISHMENTS", "CENTRAL STATIONS *vs.* ISOLATED PLANTS FOR TEXTILE MILLS", "THE SUPPLY OF ELECTRICAL POWER FOR INDUSTRIAL ESTABLISHMENTS FROM CENTRAL STATIONS", "ILLUMINATION FOR INDUSTRIAL PLANTS" AND "THE REQUIREMENTS FOR AN INDUCTION MOTOR FROM THE USER'S POINT OF VIEW", BOSTON, FEBRUARY 16, 1910.

(Subject to final revision for the Transactions.)

J. C. Parker: The first three of the five papers, *viz.*, those by Messrs. Jackson, Main and Hale, concern themselves with the question of the advantage and disadvantage of concentration in the generation of power for industrial establishments. Mr. Jackson indicates some of the advantages of concentration without, of necessity, indicating the desirability of carrying it quite so far as would Mr. Hale's recommendations which point to the generation of power by public utility enterprises exclusively. Mr. Main seems to pursue a middle course indicating that there are limitations to the concentration of power generation, while by inference, indicating that in many cases the process of concentration may be desirable. While, were the wish father to the thought, I should incline to agree with Mr. Hale, I believe that, as in all matters of human experience, the middle course comes nearer to hitting the facts.

For extreme concentration there are numerous arguments. I do not find that any of the gentlemen have emphasized one feature of the concentration, *viz.*, that of the possibility of securing expert skill and refined supervision to insure the maximum advantage from the refinements in design, which are possible in plants whether large or small. Operating refinements, on the other hand, are possible only in larger plants. Extreme refinement in engine and boiler efficiencies may be offset ten times over by the lack of attention to the loading of the equipment, the boiler drafts, etc. A plant of 25,000 or 30,000 h.p., can not only employ a higher type of operators but can readily carry the burden of a skilled engineer to supervise the operators and to systematically investigate the plant economies.

In the matter of flexibility, I incline to sympathize more with Mr. Hale's view than with that of Mr. Main, as I have had considerable experience negotiating with private plant owners and in attempting to indicate to them how they would improve their utilization of power with substantial savings. In many such cases I have found that the isolated plant is a veritable old man of the sea. Public service enterprises nowadays must, without exception, dispose of their power on a system which in some form or other is a variant of the Doherty system, of a fixed charge per kilowatt of maximum demand plus a unit charge per kilowatt-hour of energy consumption. The customer of a public service plant may, at any time, make improvements in his factory operation or motive power, whereby his maximum demand

may be kept down or materially reduced, and, therefore, the fixed cost for the maximum demand is eliminated from his power bills. With a private plant on his hands this could not be done nor would it be defensible, since the investment is already made and the labor must be paid anyway, and therefore the reduction in maximum demand will not throw off anything from the fixed costs. Where on the other hand, power is purchased, the customer essentially has the advantage of a flexible and variable investment charge carried for him by a public service enterprise. It may be said that it is to the interest of the owner of a private plant in a growing concern to do everything in his power to improve his load factor by keeping down the maximum demand so as to prevent the necessity for additional investment in the power plant as the business grows. This condition, however, does not obtain in practice. Seldom in the early stages of a business development is it apparent that some little trouble in load factor improvement is justifiable, and conditions continue to follow their unrestricted bent, until the capacity of the power plant is reached. Then the cost of making changes which would improve the load factor has accumulated to such o large sum as to be quite prohibitive. The result is that the awner is compelled to extend his plant and to again mortgage himself to a bad load factor.

The same considerations apply in the matter of efficiency as in the matter of load factor already referred to. A private plant owner has, as an inducement to improve the efficiency of his power-utilizing machinery or motors, only the coal pile saving, which is probably not more than 10 per cent of the actual cost of power. If, on the other hand, he were purchasing his power under a satisfactory form of contract from an outside company, every per cent of reduction in his bills means reducing his maximum demand and his kilowatt-hour consumption alike, thereby enabling him to make the cost economy equal to the power economy.

One other phase of the matter of flexibility in the use of purchased power is that the owner of a private plant is unable to take advantage of the progress in the development of power plant equipment as distinguished from power-utilizing apparatus. Improvements have gone on at a rapid rate during the past 20 years and seem to show no abatement at present. It seems to the speaker that were he a power user he would prefer to have the opportunity to benefit by all the improvements in the art as they come along rather, than to install to-day a plant which five years from now would be of an obsolete type. These improvements can be made by the public service companies since with their multiplicity of units, some of which are always ready to be retired from commission, they can make their improvements in line with the latest development of the art.

These considerations would indicate that the manufacturer contracting for his power supply, so far from being "tied up"

to some foreign company, as Mr. Main expresses it, is relieved from being tied up to what may be a bad investment, and is in a position to utilize every advance in the machinery peculiar to his own process, in motors, and, through the supply company, in generating apparatus.

The speaker does not seem able to reconcile Mr. Main's statement that "the isolated plant does not need to carry a large amount of reserve machinery, as it can take chances," with his earlier and more nearly defensible statement that "economy in power costs is not vital where power represents only five or ten per cent of the cost of running an enterprise." Surely for the same quality and dependability of service rendered, the isolated plant must carry a much larger percentage of stand-by equipment than the public service enterprise with its multiplicity of units; and economy on this score would hardly accord with the cost of a partial shut down of the manufactory.

With one other of Mr. Main's suggestions the speaker has an economic quarrel and that is with reference to the item of depreciation. The fact that the cost of power is, in a manufacturing enterprise, so small a percentage of the value of the product, is no reason why every effort should not be expended to secure the utmost economy in the power station. Pursuit of this philosophy to the logical conclusion would be to multiply by twenty each one of the 5-per cent elements entering into the value of the finished product and to thereby conclude that the manufacturing efficiency was a matter of more or less indifference altogether. A thousand dollars a year saved in the power plant is just as good as one thousand dollars a year saved in an office, a drafting room, in by-products, or any other way, and should be considered on its own merits absolutely irrespective of the percentage which it is of the whole. It is true that many owners of private plants do view the matter of plant economy as Mr. Main suggests, and this is doubtless a result of the fact that they are non-expert in the matter of power production and probably do not realize the importance of power plant economies. This fact constitutes another argument for the use of purchased as against privately generated power and also substantiates the alleged flexibility of power purchased.

The speaker's personal experience indicates very strongly the necessity for stopping centralization much short of what has obtained in the past. There is as pointed out by Mr. Main a certain class of business which a public service enterprise can not possibly hope to secure. Consider for a moment a condition which obtains in the centers of our large cities. Hotels have an all year and an all day demand for heat. Office buildings have an all day demand for heat during at least eight months of the year. If supplied with power by a public service company they must not only pay for the fuel burned in the central station, for the labor and supplies in a central station and for the power and boiler equipment charge, but they must in addition pay for

the extra investment to take care of from 10 to 20 per cent drop in the feeders, for the power lost in these feeders, for the use of expensive underground mains with franchise taxes thereon, but over and above they must themselves maintain a nearly identical boiler equipment and pay for a nearly identical fuel, water, boiler room labor and boiler room supply expense, which effectually puts the public service enterprise without the pale.

There is a commercial feature involved also, and that is the fact that the man contemplating a private plant for such a service always under-estimates his coal consumption whereas, the central station company knows what its coal consumption is. If then we are to talk power purchase to a man who estimates that he can develop a kilowatt-hour on one and a half to two pounds of coal at his switchboard and supply his by-product heat thereby, and if we have to tell him that under a power purchase arrangement he will have to pay for, in addition to his coal for heating, three and a half to four pounds of coal delivered in his building in the form of electrical energy, we are practically tripling his fuel bill. Of course this is a fallacy on the part of the man talked to, but it is a condition nevertheless which all sorts of missionary effort fails to eradicate.

Some of these considerations have led the concern with which the speaker is associated to do the very thing which Mr. Hale finds by a process of *reductio ad absurdum* to be an argument against the theoretical advantage of exhaust steam for heating. The Rochester Railway & Light Company is at the present time laying plans for the establishment of decentralized plants throughout the business and industrial districts of our town. These plants will consist of comparatively small and inexpensive steam turbine plants interconnected on the exhaust side and electrically feeding into our electric net work. This class of plants has one signal advantage over the central power plant, *viz.*, that they cannot possibly demand any expensive condensing equipment—that, by their very nature, these plants must be cheap and simple. One thousand kilowatts of apparatus so installed will replace 1,200 kw. of central station equipment and even irrespective of the electric feeders which they obviate will cost less than 50 per cent of what the same capacity cost in our latest and best extension of the central steam plant.

While thoroughly appreciating the experience obtained heretofore and cited by Mr. Hale, we cannot fail to recognize the principal of logic that any number of failures to prove a certain proposition do not actually disprove it. The trouble in the past has been that the decentralized plants have gone at the thing in a half-hearted way and without one tremendous advantage, *viz.*, interconnection on both the steam and electric ends, whereby, the element of diversity factor may be called into play.

Mr. Main's suggestion of the possibility of bleeding the turbines for live low-pressure steam is a most interesting one and is

illuminated by a suggestion made at the Briar Cliff meeting of the Association of Edison Electric Illuminating Companies last fall, *viz.*, that turbines should be so bled for the purpose of securing the necessary pre-heating of the boiler feed. This the speaker understands has been done in some few instances and very successfully. The advantage of carrying out this suggestion is much greater in the case of a turbine plant than in the case of a reciprocating engine plant, since it permits utilizing, in the lower stages of the turbine, steam not needed for heating. In the turbine this steam is very effective in the production of power, whereas in the reciprocating engine the steam so used is operating in the least effective part of the engine cycle, owing to the disproportionate friction and engine capacity needed for extorting the last few foot-pounds of work from the steam.

In handling, during the last two years, somethinglike 180 industrial propositions, involving the examination of many private plant schemes, the speaker has found ample confirmation for Mr. Hale's statement as to the habitual under-estimating of the cost of isolated plant power. Almost every detail is viewed in the light of an unjustifiable optimism. Investment costs such as those cited by Mr. Main are seldom recognized by the man getting up the figures for such plants. Repairs, fuel cost and depreciation rate are sadly under-estimated. It is to be hoped that some day we will have a much larger group of competent engineers undertaking consultation work in connection with small plant development—men whose experience is broad enough to lead to analyses like those by Mr. Main, which while not colored by central station prejudice, on the one hand, will be free from the predisposition to habitually advise isolated plants in preference to purchased power, as a consequence of lack of experience to correct a too optimistic system of estimating.

In closing, the speaker would like to say a few words about the besetting desire of the central station companies to secure the big business. This business is very attractive sentimentally, and for advertising purposes it is very excellent, but it is questionable whether the effort so expended is so profitable as the effort used to get the smaller business. It is true that central station companies have not done enough toward making their rate systems logical and favorable to the big plant work, but it is questionable whether the big plant is per se cheaper to supply than a number of comparatively small plants since a group of large customers will have a very small diversity factor while all other expenses of serving them with the exception of the service taps, meters and clerical work are practically identical, therefore it ensues that the large customers demand, for the same individual load factor, a greater equipment per kilowatt-hour than do the small ones, whose diversity factor may be much larger.

Charles B. Burleigh: I am inclined to feel that Mr. Jackson has touched the key-note of the present power conditions when he calls to your attention the effect of the large steam turbine on industrial development.

It has not been until within the last few years that those haveing in hand the establishment of manufacturing plants requiring the use of any considerable amount of power would not have sacrificed many other desirable manufacturing advantages to secure a location where water-power was available.

As notable examples of this, one has only to call to mind the immense manufacturing establishments located along the banks of the Merrimac, Connecticut, Kennebec and other power-supplying waterways of the country.

Had power in suitable quantity on an equally attractive basis been as readily available in the (at that time) large commercial centers located on tide-water or near large railroad centers, these locations would have undoubtedly been chosen instead of such locations as Lawrence, Lowell, Manchester, Holyoke, Lewiston, Augusta and many other inland cities so located as to necessitate the receipt of raw material and the shipment of their finished product over lines where freedom from competition, to say the least, did not tend to decrease transportation charges or facilitate the immediate movement of goods.

The last few years, however, have produced marked changes in these conditions, as stated by Mr. Jackson. The large steam turbine plant "may nearly rival the hydraulic plant in gross cost per kilowatt hour of energy delivered at the switchboard." In other words, Boston, New York, Chicago, St. Louis and hundreds of other large cities throughout the country are to-day occupying the same relation to the power consumer as though an unlimited, never failing, never varying water supply for power were at all times available, and its use for manufacturing purposes was not hampered by any abnormal developmental charge, or subject to any excessive depreciation or climatic uncertainties in order to make it available for his purpose.

These conditions, together with the comparatively recent advancement in the design and operation of high-voltage electric machinery have not only vastly increased the economical radius of both steam and hydraulic developments, but are making valuable, water privileges for power purposes which have heretofore been considered not worth developing, as well as making desirable for manufacturing purposes locations which could not previously be considered.

Due in a large measure to the foregoing conditions, the time is fast approaching, if it has not already arrived, when few if any manufacturers having use for power, in large or small quantities, within a radius of 10 or even 20 miles of a large power distributing plant, can afford to devote the necessary time, energy and capital to the production of their own power.

It is with extreme hesitancy that I limit the present radius in the above statement to twenty miles. I am not sure it should not be extended to at least 50 miles, and I have no doubt that the developments of the next few years will result in lower production and transmission costs, which will permit of even further economical extension.

Consider for a moment what these conditions are capable of doing for Fall River, where all of the many thousands of tons of coal burned per annum in her immense textile establishments have to be carted up hill at an expense of from 30 to 75 cents per ton; and also at New Bedford, where notwithstanding the fact that it is located on tide-water, over 80 per cent of all the fuel burned in the city for power purposes is teamed at an average cost of some 30 cents per ton; and at Lawrence, Lowell and Holyoke, where in each case, a central electric power plant ideally located with reference to the most economical utilization of their water-powers would not only serve their present available market, but would more than double it, and the land now occupied by canals would be made available for the location of additional manufacturing industries, while the land values and saving in canal and water-wheel upkeep would very nearly, if not quite, pay for the development, to say nothing of the immense benefit that would accrue to the several communities.

While to-day the power producer and the power consumer are practically the only ones actually interested in these conditions it will be but a comparatively short time when they will realize that a percentage of their public tax is chargeable to the street wear and traffic congestion in large cities, incident in a measure to the delivery of fuel and removal of ashes, and when the tax payer not primarily interested in the production or consumption of power begins to realize that he is obliged to contribute for the upkeep of conditions no longer necessary to the prosperity of the community, I am inclined to feel that you will see the enactment of laws, pertaining to large cities at least, which will make the so-called isolated plant less desirable and the central station even more attractive.

Mr. Main in the opening of his paper calls attention to one of the most important points in connection with the consideration of the isolated plant versus the central station and I can most heartily endorse his statements that "the cost of power in a textile mill, as well as in many other classes of manufactures, is but an incident to the ultimate result," and that "a saving of 10 per cent in the cost of power would represent a saving of not over one-half of one per cent in the cost of the product."

This being an undisputed fact, it is obvious that there are other features in connection with the production of power of vastly more importance than the cost, and we may dismiss this item of the comparison with the statement that power is available from the large steam turbine or hydraulic central station or isolated plant at costs so nearly comparable, and having so little bearing on the ultimate results as to be worthy of little or no consideration.

What then should we consider as the deciding factors?

Reliability should without question be considered of prime importance as the fixed charges in an industrial plant are continuous and any interruption to, or impairment of production

represents the widest and most important variable with regard to the earnings on a given investment.

What, then, may be considered the reliability of operation of a manufacturing establishment furnishing its own power as compared with one receiving its energy from a central power plant?

Let us consider first the producing machinery; here there is no material difference in either case, and I feel that those interested will concede that motors and the interior wires and fittings are as reliable as belts and shafting, which brings us to the prime mover in the isolated plant, and the entrance to the service from the central station.

Considering the isolated plants prime mover, I feel that I am correct in the statement that no 10 per cent of the manufacturing establishments, large or small, have duplicate prime movers, while central power distributing plants have many similar units, the overload capacity of a small number of which would be equal to the full capacity of any single unit.

The average isolated power plant being but an incident to the main object of the business, is given less attention by the management than is similar apparatus in the central plant, where, on the uninterrupted economical production of power, wholly depends the success of the object of the investment made, for which reason there can be no question in regard to reliability up to this point.

But, you say, the transmission line from the central station to the point of delivery is an item of unreliability not necessary to consider in connection with the isolated plant. Let us therefore consider the central station location.

In order to equitably do this, we must give some consideration to the items of difference between the water and the steam station.

With regard to the reliability of output from the station there should be no material difference because if there be any source of anticipated unreliability from the water-power, such as high or low water, anchor ice, or any interruption to the efficiency, we may consider that in order to make it commercial it has been provided with a steam relay of such capacity as will meet any possible contingency.

The steam station is or should be so located that its source of fuel and water supply can under no conditions be interfered with, while the hydraulic station must of necessity be located with reference to water supply to which the source of fuel supply is secondary, in fact the location of the hydraulic station is comparable to the old water-operated manufacturing plant in which all other considerations in regard to location are subservient to the hydraulic conditions.

The location of the steam operated isolated manufacturing plant is selected in accordance with its market, source of supply of raw material, ease of shipment, availability of suitable help, and in some industries, on account of climatic conditions, or in other words, its source of fuel supply is of minor importance.

I feel that you will agree with me that the transmission of energy by electricity over wires permanently and substantially installed, and not liable to be affected by strikes, hold-ups, wash-outs, snow-storms, floods and other natural causes to nearly the extent that the transmission of fuel is, demonstrates this last item to be fully as, if not more, reliable than the other.

While there are many other items of minor importance emphasizing the added reliability of the central station over the isolated plant, I feel confident that in view of the foregoing you will agree with me that the item of reliability is better conserved by the central station than by the isolated plant.

Flexibility is another item worthy of consideration. This item is one of admitted superiority of the electrical drive over the mechanical drive, and as the central station drive must of necessity be electrical, the comparison of this feature can only be between the electrically operated isolated plant and the central station, and a comparison on this basis is all in favor of the central station.

If a manufacturer wished to operate say 25 per cent of his plant over time from an isolated plant, he would do so at extremely poor efficiency while if supplied from the station, power is used at maximum efficiency so far as the consumer is concerned.

Additions and alterations can be made, without in anyway interfering with the continuity of operation, and changes in product and capacity have no effect on operating efficiency.

Less financing for a given output is required, and to revert for a moment to the cost item, I can perhaps best illustrate the point which I wish to bring to your attention by detailing a recent investigation I was privileged to make in this connection.

A 100,000-spindle print cloth mill was projected and the question arose with regard to the source of power. It had been considered advisable to equip the property for the electrical operation of the producing machinery and the scheme had been financed to the extent of some $1,800,000.

Carefully prepared estimates demonstrated the fact that the necessary power plant would require the expenditure of some $225,000 thus leaving $1,575,000 available for the mill and its equipment of producing machinery.

It was further estimated that 100,000 spindles should produce sufficient yarn to operate 2,400 looms, each producing 90 yards of cloth per day, having a sale value of 3½ cents per yard, resulting in a yearly production of $2,260,000 worth of finished goods at a manufacturing cost of $1,810,000 when operated from its own power plant, showing a profit of $450,000, or 25 per cent profit on the invested capital.

The operating costs on the power plant included coal at $3.50 per ton delivered in the coal pocket; 5 per cent depreciation on the machinery and 3 per cent on the buildings. The cost also included 5 per cent interest on the power plant investment and

on this basis it was estimated that the power cost at the switchboard would be $22 per h.p. per 300 ten-hour days per year, or a total of $66,000 per year for power.

Figures were obtained from the local steam turbine equipped central station, located on tide water and using fuel at a cost of $3.20 per ton delivered into the boilers, of 1.5 cents per kw-hr.

The acceptance of the above proposition permits of the investment of the $225,000 allotted to the power plant in producing machinery, and it will be noted from the foregoing figures that but 5 per cent was charged against the power plant, while 25 per cent was shown as the profit on the total invested capital; therefore that proportion of the capital invested in producing machinery shows much better returns, which is a strong incentive for investing the money where it will show the greatest profit.

Contracting with the central station for power and increasing the producing machinery incident to the investment of $225,000 increases the yearly output of the mill 14¼ per cent and the sales price of the finished goods becomes $2,583,933.

We would anticipate that our power cost had also increased, first due to the fact that we feel that it is costing us more and second that we are using more power, due to the fact that we have enlarged our mill.

In the first case we used some 3,000 h.p. and in the second case we have apparently used some 3,500 h.p. This is not the case, however, as I will attempt to explain. It is a fact that for the sale of argument we have increased our producing machinery to the extent that 500 h.p. additional capacity is required to operate it.

The textile manufacturer will tell you that his mill shows a 90 per cent load factor on the basis of ten hours operation and for the sake of argument we will take this as a basis, for when operated from his own plant, it does.

When operating at a 90 per cent load factor and paying for current by meter, however, the meter records the current consumption each instant of operation. In other words, a machine stopped and started 60 times a minute, under such conditions that the intervals of stoppage just equal the intervals of full load, would record on the meter as operating one-half minute at full load.

Tests made with curve-drawing electric meters, show that the power consumption of textile manufacturing processes, with the exception of ring spinning, average about one-half of maximum, and that the spinning averages about two-thirds of maximum. Spinning consumes about 60 per cent of the power required in a mill. The central station customer obtains advantage from these conditions, which he would not if operating his own power plant, because his investment, depreciation, coal-pile and labor are not so sensitive as his meter.

First, if all the machinery in the mill stroked together we would

have a load factor when operating by meter of one half of forty per cent of 0.90 plus two-thirds of sixty per cent of 0.90, or 54 per cent, for the entire mill. But all the machinery does not stroke together, nor does it break joints (so to speak) entirely, and this feature is the result of a disputed point between the central station operator and the textile manufacturer, the former claiming that from his meter readings the textile mill seldom if ever shows a better ten hour load factor than 75 per cent while the manufacturer insists that an experience of many years has shown him a 90 per cent load factor. Again for the sake of argument we will admit that they are both right.

The central station man's tell-tale (his meter) permits no lost motion but records actual conditions, while the manufacturer's tell-tale (his coal pile) is less sensitive in taking advantage of these conditions and fails to record them. It is therefore equitable to figure on the basis of experience.

As 3,500 h.p. for 3,000 hours equals 7,835,700 kw-hr., and 75 per cent of this equals 5,876,775 kw-hr., which gives at 1.5 cents, $88,151. as our total power bill.

Now what has it cost us to do this?

1. It has cost us $22,151 per year.
2. We have sacrificed our independence.

What have we gained by this sacrifice?

1. We have increased our production $323,933 per year.
2. We have a more reliable power supply.
3. We can devote all our time and energy to our legitimate business.
4. We have no need to worry about the fuel market.
5. We can make alterations without regard to the power plant.
6. We can run any department overtime at maximum efficiency.
7. We can change the style of goods without change in our power plant.
8. We can select a location ideal to manufacture without regard to power.
9. We have made $51,809 additional net profit on our investment.
10. We have earned 27.8 per cent on $1,800,000 invested instead of earning 25 per cent as would have been the case had we installed our own power plant.

If you are disposed, however, to question the position I have taken on the load factor, pending more careful investigation of the subject, if we use the same load factor of 90 per cent we have still increased our profits by $22,405 over the use of the isolated plant on the given investment of $1,800,000.

Second, consider for a moment the mill using exhaust steam and hot water in preparation work and heating. With regard to heating, I believe I am correct in the statement that about 80 per cent of the heating of textile mills is done when the ma-

chinery is not in operation and this is the case in many other classes of manufacture, for which reason the heating can be practically eliminated from the consideration so far as the power plant is concerned.

In the most extreme case, named by Mr. Main, of saving to be effected by the use of steam as a by-product, the saving is $8.00 per kw-yr. or some 23.5 per cent. Let us add 23.5 per cent to the cost of the power in the mill I have taken as an example, under the worst conditions for comparison of 90 per cent ten hour load factor where our additional profit due to the use of central station power was $22,405 and our power cost was $88,151 per year. Our increased profit is reduced by $10,715 but we still have a profit over our isolated plant operation of $11,690.

I feel that the foregoing figures demonstrate that maximum production is the item of paramount importance to the manufacturer, which is to a large extent subservient to and dependent on reliability and flexibility, all of which are best conserved by the central station at costs at least commensurate with the results obtained.

Norman T. Wilcox: In most cases the advantages of using exhaust steam where there is a steady use for it the year around cannot be successfully questioned, although it should not be forgotten that there are some disadvantages in distributing low pressure steam over considerable areas, such as might be present in the case of the larger mill plants.

The whole trend of modern development the world over is towards centralization. The laws underlying this development are peculiarly applicable to the generation and distribution of electric energy for power and other purposes. This must ultimately result in the greater portion of power being generated in great, modern central stations. These stations can take advantage of the larger load factor and greater economy resulting from the great diversity of use for power, lighting and other purposes.

When we consider that the larger central stations are already growing into wholesale power plants, that with distributing systems complete can be installed for approximately one-third the cost per unit of a lighting system only, and that the total cost of such a complete system will be as low, probably lower, than the average mill plant of even 2,000 to 5,000 kw. capacity, we may well pause before spending money for a lot of small plants with their relatively much poorer economies.

On the other hand, it should be clearly borne in mind that investment as well as distributing losses for a wholesale modern power system will not be more than one-third of those of a lighting system only. Then again, the great advances made in the art of insulation, manufacture of cables, transformers, etc., make it possible for a modern plant of this character to generate and distribute current to mill plants with even greater reliability than that afforded by the isolated plant. In addition to this, the

big central station has the practical advantage of vastly greater economy in the cost of generating current, this due to its more efficient equipment, better load factor and ability at all times to benefit from a highly skilled operating force capable of applying refinements and checks which are necessary to the attainment of the best economies.

Relay

There are several conclusions in Mr. Main's paper with which I cannot agree. The logic of assuming that no less relay is necessary for the 2,000 kw. isolated plant than for the central station is very much open to question, as the central station will have a much larger plant and more competent force; therefore, less chance of interruption to service. The central station will require less relay equipment to furnish the same reliability of service. Modern central station distributing systems, with a 13,000-volt underground system, are as reliable as belt drives.

As most of our mills are not dead, but are progressing and growing, and some of them quite rapidly at that, is it not reasonable to assume that by a second year at least, the 2,000-kw. plant outlined in the paper will be called upon to put in a third 1,000-kw. unit, necessitating 25 per cent to 50 per cent additional investment per kilowatt of capacity? This would make the total cost per kilowatt, instead of $105, as in the case of the turbine station, $130, or possibly $150 per kilowatt of capacity.

Depreciation, Etc.

When it comes to the matter of depreciation and cost for equivalent service, I fail to see why more depreciation should be charged against the better cared for central station equipment than would be allowed in the case of the mill plant. If anything, rather more depreciation should be charged for the isolated plant than for the central station equipment. This tends to increase the cost of isolated plant supply. In order to meet the competition of the central station, due to the introduction of modern apparatus, the isolated plant must also replace its machinery and accept the same or greater depreciation than the central station.

Checks on Plant, Etc.

As steam is used from a common boiler at all points in the mill yard, it is not practical to obtain such operating checks as to enable the isolated plant to even approach the net economies obtained by the central station with its larger and more economical equipment. The superior economies of the modern central station are due to constant and close hourly and daily checking, a practical impossibility with the mill plant. Omit this checking for ten days and the result is a loss of 10 per cent in the plant efficiency. A longer period will materially increase this loss. This being the result of experience in the best central

stations, what must be the relative efficiency in the mill plant where these checks may not be obtained?

Cost per Kilowatt-year and Kilowatt-hour, and Effect of Load Factor on Price

Results obtained by a large central station serving textile and other industries, this station having several power feeders varying from 500 to 1800 kw. capacity in daily use, show on a 3,000-hour-year basis an average 10-hour load of not to exceed 85 per cent, and this with all the advantages of diversity factor. As this station meters its energy to the customer *at the motor* in comparing services, the 5 per cent or more loss from customer's generator through switchboard and distributing system to the motor terminals should be deducted, making the real load factor 80 per cent.

In many plants, this annual 10-hour load factor is not over 70 per cent or 75 per cent. Taking the case of the color mill, an application of the 80 per cent load factor would result in the use of 2,400 kw., making the rate slightly more than 1.4 cents per kw. as compared with the impossible 100 per cent load factor assumed with 3,000 kw. annual use and estimated kilowatt-hour price of 1.1 cents. This would be approximately correct, as the only variable in the kilowatt-year cost would be the slight difference in cost of fuel for less number of kilowatt-hours, other expenses remaining the same. Likewise if the hydraulic power at $0.012 per kw-hr. had been figured on a 2,400-kw-hr. per year use, instead of 3,000, the kilowatt-year cost for the hydraulic power would be $28.80 instead of $36, and the horse power-year reduced to $21.60. Similarly, the kilowatt-year cost of $36 is reduced to 2,400 kw-hr. × $0.012, = $28.80, and the $27 per horse power is reduced to $21.60. These examples illustrate the danger of not clearly distinguishing between terms of capacity and actual work done and to be paid for by the customer.

Central station power at a definite price per kilowatt hour is a known quantity, not an estimate, and is easily checked from day to day, and for each department if desired; but cost of power to the isolated plant is an unknown quantity with cost depending largely on the varying personnel of the mill staff, as well as relatively poorer attainable efficiencies and other factors.

In order to obtain the insurance of service and price incident to the supply obtained from a big central station, the mill man can well afford to pay 10 per cent more than his estimated cost in order to obtain the central station supply.

In considering the price of the isolated plant and cost per kilowatt-year and per kilowatt-hour, load factors should not be predicted upon estimates based upon intermittent daily observations or special tests. If we would avoid disappointment and loss we should make the basis of comparison actual yearly operating conditions and costs, with their inevitable con-

tingencies, including competent supervision. A few careful and consistent checks of this kind, if they were possible, would reveal that 80 per cent is a remarkably high yearly load factor, although it may appear from intermittent observation that the load factor is apparently higher. Consequently the kilowatt-hour cost of the isolated plant will prove much higher than anticipated and generally believed.

Incidentally, I believe that in the majority of cases our mill friends will ultimately realize that the central station will be able to furnish current and service which the mill men will be warranted in accepting.

H. B. Emerson: It is conceded to-day, by practically all who have studied into the matter, that the flexibility of electric power, places it as the foremost of all operating forces; and the points brought out by Professor Jackson's paper only tend to confirm this conclusion.

The matter of concentration of the generating plant, however, I believe must be decided by individual conditions. If the question involves only the laying out and building of a strictly new plant, then I most heartily favor a single generating station, with modern prime movers; also the placing of the manufacturing buildings so that the greatest economy can be obtained outside as well as inside the station. This, however, can not always be accomplished in old plants; for example, I know of a case where the plant has outgrown the original distributing potential of its station, where steam was needed in the process of manufacture too far away to economically transmit it from the station, and where both of these difficulties could be overcome more economically by building a second generating station than by adding step up transformers and a new steam plant for generating only steam for the manufacturing processes. Such cases are undoubtedly special, but engineers are destined to encounter such special cases, and they require even greater study and care in planning for the still further development of the plant, than would an entirely new plant, if the owners are to obtain the greatest return for the money they expend.

Central Stations *vs.* Isolated Plants

Regarding the question of whether the power should be obtained from a central station or an isolated plant for industrial purposes, I believe here, again, we can only decide after we know the conditions to be met in the individual plant, as the weight of argument will undoubtedly be in favor of the first in some cases, and of the second in others.

Mr. Main's point regarding use of exhaust steam in certain plants is well taken, and in many cases would be a predominant factor in deciding for the isolated plant.

In some plants the cost of power is a small item as compared with the other costs of manufacture, but in many plants it is a leading factor, and whether large or small it is looked after very

sharply in an up-to-date plant. No official of a company is going to fool himself as regards the costs of one department by trying to hide part of them in the costs of another. To-day it is a cold business proposition, one mill or factory against another, and if a small percentage can be saved in the power department it is looked upon just as favorably as though it was saved in another department.

If the central station can make that saving to the owner of a plant, any broad minded man will let the station do it; on the other hand, the saving must be proved. The manager knows what his fuel, labor, supplies, repairs, insurance, etc., cost him, and if he finds he can produce his power for one cent per kw-hr., he will not pay a central station two cents for it.

I know of a textile plant generating its own power with turbine-driven generators and using a large percentage of the steam from the second stage of the turbine for dye house purposes, which is producing its power at less than one cent per kw-hr. including proper items for insurance, depreciation and taxes.

The figures check those given by Professor Jackson very well in toto, but are divided somewhat differently; the fuel cost being somewhat greater but the labor cost less. The saving obtained, by bleeding the turbine, also compares favorably with the saving shown by Mr. Mains' figures for the use of receiver steam.

I cannot agree with Mr. Hale's deduction regarding the use of exhaust steam. The methods employed by the central station are hardly comparable with those of the manufacturer. The central station has had to transmit its exhaust steam a considerable distance, and its use has been governed by parties not under their jurisdiction; some days (on account of cold weather) they would have a heavy call on their mains, and perhaps a few days following very little would be used. The manufacturer does not depend on his heating alone to use the exhaust, but has processes of manufacture requiring steam at low pressure, and the departments employing these processes are placed very near the power station and the drips returned to it at fair temperature. Further, if he did not have this exhaust steam to call upon he would have to furnish it from some other and more expensive source.

While I should favor the buying of power from a central station that could supply it at less or even at the same figure the isolated plant can produce it for I am, yet, to be convinced that a broad rule can be set forth to definitely decide the matter.

Lighting

I thoroughly agree with Mr. Stickney that the subject of industrial lighting deserves a great deal of study. Not only different plants require different systems of lighting, but the various departments of the same plant may require different illumination. One point which he did not mention, however, is one which was brought to my notice during some recent

illuminating tests in a mill, where it was found that fully as much attention had to be given the distribution of the lighting units as to the diffusion of light.

With the same foot-candles in each case, the single tungsten drop lamps gave much more satisfactory illumination to the operatives than either the intensified arcs or tungsten clusters, owing to the better distribution of the light between the machinery. In other parts of the same mill, the intensified arc gave the better satisfaction, and in still other parts the enclosed arc was most advantageous. Where color matching was required, the dioxide vapor lamp was accepted as best adapted for the work.

A manufacturer to-day cannot afford to be without good illumination, for aside from better quality and quantity of light, there undoubtedly is a physiological effect upon the operatives which is advantageous, and the man who lays out a scheme of lighting for a factory must know not only the illuminating power of the lamps and their value, but must familiarize himself with the processes of manufacture in that plant.

Motors

Mr. Nye's expression of the requirements of an induction motor is undoubtedly to the point, but it must not be forgotten that the questions of power factor and efficiency must be reckoned with, especially in the larger installation, in order to obtain continuity of operation in the station as well as in the factory.

A motor can be too sturdy in many cases when the interest on the investment is taken into consideration, and there are two sides to the question of how much overload capacity is necessary for the manufacturer to provide in his standard motors. A great many industrial plants require practically no overload capacity in their motors, while others must have a considerable margin in the motor to meet the maximum demand required of it. It seems, therefore, that this question must be decided by the user and his engineer, and motors ordered to suit the requirements of their factory. Most of the electrical manufacturers of to-day have two types of motors, one for the first conditions mentioned above, and another type having considerably greater overload capacity to meet just the requirements stated as desirable by Mr. Nye. By having these two types of motors, better characteristics are obtained for each service than could be obtained if a single motor was designed to meet all kinds of service, and allows the customer who has the lighter work to obtain his motor at a less cost.

N. W. Dalton: In textile mills where the units require little power, the superiority of an electric drive admits of no question. Some of the conclusions derived from experience with induction motors in large plants are herein outlined. While in special cases the individual drive may be installed, with a large number of tiny motors, generally the group drive should be used.

What principles should govern the number of machines in each group?

First, as few *different* sizes of motors should be used as possible. Consideration of the requirements in the way of spare motors, repair parts, switches, wiring, etc., will make this clear. A study of the possible grouping of machinery in the different mills (carding, weaving, spinning, etc.) will show that a few motor ratings will cover all cases.

Second, as to motor speed. A large proportion of textile machinery is designed to be driven from slow running shafting and it follows that motors should be of moderate speed. The argument against this view is answered in every plant where the lower speed motors prevail. While speeds near 1000 rev. per min. may look right to the purchasing agent, the man who has to drive the slow running main shaft will make good the cost of the larger frame if the motor is wound for double the number of poles.

Floor space is too valuable to devote any of it to motor and driving belt. Motors should therefore be inverted and bolted to the ceiling at truss line.

Third, grouping of machinery should be limited to 50 or 60 h.p. Making our motors something under two tons. The reason of this limit is ease of handling. These motors can be drawn around mills yards on the ordinary wagon or truck. They will go up and down on the ordinary elevator without the use of hoisting tackle. The writer uses a hand truck for drawing motors around mills. This is merely an open plank frame with small cast wheels, the opening being large enough so that the frame can be drawn around the motor. The frame is fitted with an iron tripod. From the center of the tripod is dropped a threaded hook, while a hand-wheel with nut gives the necessary power to lift a two-ton motor from the floor, whence it can be easily drawn to its place.

Larger motors, say four or five tons, must be moved on skids with rollers. Some types of older mill floors will not stand this use and timbers must be laid for rollers, and in some cases shores used.

Spur-geared blocks are most economical of effort. Those of one ton rating weigh 80 or 90 pounds so that a man can easily place them. A pair will quickly hoist a motor in to place, while a single one furnishes the necessary power for replacing bearings and making repairs—work that does not necessitate lowering the motor. Thus by limiting the motor size we can get along with less repair apparatus, which is a great consideration in emergencies.

Fourth, while smaller motors than the largest size adopted are necessary, motors should in all cases be kept as near the largest size as possible. Smaller motors mean danger from overloading, due to shafting out of line, hot bearings, and other minor troubles. Such things are relatively unimportant in the larger sizes. Still, small sizes must be used in textile work where

large areas of some kinds of machinery consume but very little power.

Reliability

While the electric machinery will cause fewer interruptions in the production of goods than almost any other part of the plant, still a stoppage of a motor or generator causes more attention than almost any other accident. All efforts towards greater reliability will be well spent, as the electric drive still has a reputation to acquire and maintain.

The greatest cause of failure in induction motors lies in the starting devices. Immunity from delay is best secured by having these entirely separate from the motors. A voltage reducing device in the motor leads is to be preferred. In case of failure it may be short-circuited and a temporary starter used, until repairs can be executed, without delaying production. When the starting device is located inside the rotating secondary, the matter of repairs may involve a considerable delay. In this limited space, and exposed to dirt and careless usage, no system of sliding contacts can ever give satisfactory performance.

The motor with internal starting resistance has a high starting torque with low starting current. The resistance of the secondary when up to speed is very low, thus giving the motor little slip. These are desirable characteristics, but they are outweighed by the matter of reliability. The lack of reliability seems to be more in the operator than in the motor, for some of these motors run several years with no delays whatever.

The device always furnished for starting is an auto-transformer with a double-throw switch. Would it not do to use a cast iron grid resistance? This is simpler, cheaper, easier to install and repair. The starting position should be held by hand against spring pressure so that the switch cannot be left in the starting position.

With the oil-immersed switch, it is best to have lock, so that the switch can not be thrown to the running point until it is first drawn into the starting position.

For sizes of 100 h.p. or less, and voltages not over 600, air-break switches are the most satisfactory. The oil switch is awkward to install and difficult to inspect. Often it has wood mounting and flexible leads. Some would not be safe to operate without the oil, so that the oil is a necessary adjunct and not a additional safeguard. The oil itself besides being a nuisance is often a source of danger, as some grades are very easily ignited after standing for some time. The air-brake switch is constantly in sight of the operator and any trouble is seen; while the oil switch often gives the first hint of trouble by refusing to work. Practically all the troubles of air-break switches are confined to burning of contacts and cutting in hinges; minor troubles which are easily repaired.

The air-break switch will prove unsatisfactory if used in sizes under 100 amperes capacity from want of mechanical strength,

though it does not follow that all switches of higher rating are mechanically as strong. Switches must have a quick break attachment. This, unless carefully designed, is apt to give trouble. It should be strong and not interfere with operation of the main switch in case it gets into trouble. Carbon-break switches have not proved satisfactory.

Motors of the smaller sizes do not require any starting device but may be thrown directly on the line. The limit of size to which this method of starting may be carried depends on the connected machinery. Too sudden acceleration is destructive to belting. In general, textile machinery is disconnected from the shaft while the motor is accelerating, so that the starting torque required is light.

The second greatest cause of motor failure is due to bearing trouble. The bearing metal is babbitt except in smaller sizes where bronze is sometimes used. Experience with bronze demonstrates that it is very unsatisfactory. Where babbitt is used the air-gap should be sufficient to allow for the starting of the metal before the rotor strikes the primary. The smoke when the babbitt runs will attract the attention of the attendant and the motor can be stopped before the laminations strike. The latter will sometimes shift cutting the insulation of conductors.

Overloads are supposed to be prevented by fuses or safety devices. The exigencies of service are such that this is rarely the fact. A larger fuse is an easier solution than a little care and judgment. The real protection against destructive overloads lies in the use of a portable ammeter and the exercise of considerable vigilence by the electrical department. Motors should be capable of carrying reasonable overloads, and the behavior of those overloaded should be watched to ascertain the effect on temperature. In the factory where the writer has charge, not a single motor has been lost by destruction of windings, except where laminations shifted due to bearing failure.

A word as to motor design. Ventilating slots through the iron laminations are useless as they are promptly plugged by flyings. The cleaning of a hundred or more motors is no small task and if left for nights and Sundays will not be done. The only solution seems to be to clean while running. The rotating parts should be so designed that the air blast will clean them when motor is working. This is not universally the case with the motors now furnished.

The bearing on the pulley end of a motor should be designed so that it may be replaced in case of failure without the removal of the pulley. Pulleys have a way of rusting fast to the shaft and requiring some time to effect their removal. On some of the smaller motors an opposite effect has been noted. The pulleys work loose and destroy the key-seat in the shaft. A more liberal design of shaft and key is needed.

If paper pulleys are used they should have metal hubs. The

variety having a piece of metal inserted to hold key will not stand up in hard service.

Lighting

Mills where a large proportion of the help consists of women operate from 7 a.m. to 6 p.m. only. The lighting hours are few in the year, but the lighting must be ample. We are practically confined to the carbon filament lamp, for the problem is to keep down the first cost of the installation. On alternating-current circuits the enclosed arc lamp with proper globes and diffusers gives so little illumination as to be out of the question, the tantalum lamp has no length of life and the tungsten lamp is too delicate and costs too much. In certain places where the cost of power enters, due to the necessity of burning lamp for long hours, 27 volt tungsten lamps are fairly satisfactory although in some instances they blacken very quickly.

Local lighting, inherited from gas lighting days, seems to be the desire of the mill from the office to the machine hand. General illumination has to be demonstrated before it will be accepted. In general this is the better form, but not universally. In some mills a compromise form has to be adopted.

In calculations of lighting, a certain, or rather uncertain, factor is introduced by the character of the flyings that collect on the lamps. In a spinning room for instance the wool flyings are easily cleaned from lamps and full illuminating power is secured. Where the flyings carry certain amounts of dyestuffs and starch, allowance must be made, as the labor of cleaning and the inconvenience caused thereby amount to more than the excess of power necessary to ring the lighting up to standard.

Running boards with wires cleated to them should never be used. Drops of incandescent lamp cord are a nuisance and should be done away with wherever possible. They should never be placed in a card room nor used to light Axminster looms. They are successful in spinning and drawing rooms.

Clusters of a cheap variety are the best solution for mill lighting. They should have heavy galvanized iron shades. The leads are protected by being carried down the iron pipe support. The shades receive the blows of ladders, poles and other long objects carried around mills and save the lamps from destruction. Where the machinery is of a class to transmit little vibration to the building, clusters may be rigidly secured. Some classes of machinery will cause the building to vibrate, no matter how heavily built. Under these circumstances it is necessary to hang cluster stems from a hook.

Three phase circuits are best for power, but for lighting, the matter of balancing is a nuisance. If we are confined to 125-volt lamps, the amount of copper in a mill 1000 feet is rather large. The best distribution appears to be a geometrical arrangement of 250-volt three-wire circuits. By arranging two single-phase circuits in quadrature and alternating each bent

on the 250-volt circuit there is not the least trouble in keeping the sides of the three-wire system balanced and the circuits will balance on the three-phase sides. This easily acquired balance continues through the many changes in lighting that a growing plant affords.

H. W. Peck: These papers are much more general than I would wish. We need data regarding actual facts obtained, giving good, bad, and average performance, especially the last for the sake of the manager or investor. It is noticeable in both Mr. Jackson's and Mr. Main's papers that they give practically the best performance of the machinery which they are discussing, and state this fact, but they do not state what they have found to be, or believe to be, average performance, *e.g.*, Mr. Jackson says, "The cost is probably fully that large," and again, "The cost is ordinarily much higher"

I would suggest also that in discussions of this kind the cost and other items regarding performance be reduced to the basis of the kilowatt-hour. It is conceded by the authors that electrical distribution of power is most general, so that this basis will apply in the majority of cases. If the plant is so small, simple and compact as to make mechanical distribution a possibility—and investigation shows it has advantages—a correction factor due to these advantages can readily be applied to the determined cost of electric power at the switchboard. Thus Mr. Jackson's "Round estimate of the cost of power in machine shops and the like is $60 per h.p.-yr." becomes 3 cents per kw-hr. His costs of 0.65 cents and 1 cent per i.h.p. per hr., which he increases by 50 per cent for mechanical distribution, can with equal correctness be increased by from 50 to 70 per cent to give the cost per kilowatt-hour at the switchboard, thus enabling a direct comparison with central station power. Similarly, Mr. Main's figures for pounds of coal per horse power per hour increase from 1.75 and 3, to about 2.95 and 5.05 lb. per kw-hr. at the switchboard. The performance given on the basis of the indicated horse power per hour can be changed to a basis of a kilowatt-hour by multiplying by a factor between 1.55 and 1.7, the former for large units of, say, 1000 kw. capacity, and the other for smaller units of about 100 kw. capacity.

I would take exception to several matters in these papers as a general proposition, applying to textile mills, or to any other industrial establishment; in the first place, to the position taken that reliability is of secondary importance, and that no spare units should be considered necessary for an industrial establishment. This is certainly far more important for a small plant with only one or two units which would be very seriously crippled by the breakdown of one unit, than for a large central station with so many units that the load of any one could easily be carried by the remaining units. This gives a real factor of reliability without cost additional to what would be determined by good engineering practice as regards the amount of load

normally carried by each machine. Likewise, if the power is as small a matter as five per cent of the rest of the business of an industrial establishment, it seems poor judgment to skimp on the power plant, which may cause a cessation of the other 95 per cent of the business. Both gentlemen concede the increased reliability of the larger power plants. I have in mind two comparatively small plants in Rochester where the cost for break down service from the central station during the first year of operation amounted to, in one case, 30 per cent of the operating cost of the plant; in the other case, 25 per cent. If central station service had not been available in these cases, and a spare equipment had not been provided, the business would have been practically shut down. I do not see, either, how it is possible to install these plants within such close limits of the actual requirements. In my experience with industrial plants, there is a very marked seasonal variation, and in most cases, a steady growth in power requirements. This, of course, makes the average load factor, considered over several years' time, much lower than the load factors given in these papers. In our experience, also, the lighting of the establishments amounts to from 10 to 25 per cent of the power requirements, and is of use for but short periods. This decreases the load factor much below that given in the papers.

This brings to mind another advantage which the central station possesses. Its growth has been steady but gradual and it has had the opportunity of making its additional equipment of the most modern type. This most efficient equipment can be used at the average load for the long-hour use while the less efficient and less valuable machines are operated for the peak load.

Neither paper considers the item of profit which should be earned on the power plant investment and operating capital to the same extent that it is earned on the rest of the investment —possibly 10 per cent; possibly 20 per cent; or at least to the extent of the central station profit, say 5 per cent. Mr. Main also passes over very lightly the matter of supervision on the part of the manager. I have found that the managers are required to expend considerable of their time and thought on the power problem. These managers are experts in business matters but are not engineers, and their time is expended to small advantage in power questions. In one of the cases cited above, where the breakdown service was so expensive, the manager said that he had spent about two-thirds of his time in connection with his plant.

As to the division of central station costs mentioned by Mr. Main, I would say that the production cost is about one-half; the distribution about one-third; and the general expenses, including advertising and commercial expenses, about one-sixth. In the specific case of the smallest customers who use just enough power to pay the minimum charge of one dollar, the central station companies certainly do lose money, *e.g.*, with an

8 cent kw-hr. rate for current, and a one-dollar-per-month minimum charge, the cost of maintaining and reading the meter, billing, and collecting, amounts to slightly over one dollar, while the $12\frac{1}{2}$ kw-hr. may not represent more than 25 cents. For a large customer the meter costs are, of course, practically a negligible part of the total expense.

I have yet to find any industrial establishment that knows even within approximate limits the cost of its power, either in toto, or per unit. Such costs were recently promised me by one establishment, with the assurance that they had them exactly, and that it would be a simple matter to take them from the books in shape for me to use. They have since told me that it will mean several months' work to get this data, as they were quite surprised at the manner in which the costs had been entered. In this particular place they had a watthour meter on the switchboard, which in itself is quite unusual. Where they have not this means of knowing the amount of power generated the actual amount is almost invariably over-estimated.

R. D. De Wolf: In the article by Mr. Hale the writer has reached certain conclusions in regard to the use of decentralized plants, basing these conclusions on the experience met with under certain commercial and operating conditions. It should also be noted that the small plants abandoned by the Edison Electric Illuminating Company of Boston were not so situated that use could be made of the exhaust steam from the plants. As pointed out in Mr. Main's article, the mill which can use all of the waste products from the power plant will have the lowest cost; and this same condition exists when the power plant is operated by a central station company and that company is in a position to sell its waste products.

There are several conditions existing which make the operation of a decentralized heating and power plant particularly attractive. In plants of this type the operating conditions are determined not by a widely fluctuating electrical load, but by a fairly steady heating load. The heavy overloads met with in operating generating stations, lasting from one-half hour to an hour or two, are not encountered when the primary purpose of the plant is to supply steam for heating. On account of this great improvement in the load factor on a plant it is unnecessary to carry large reserve power units for peak loads, and the plant can be operated at or near its point of maximum efficiency the greater part of the time. As the plant is necessarily a non-densing plant, complicated auxiliary apparatus is dispensed with, and a simple type of machinery installed which can be operated by comparatively unskilled labor and requires less attendance. Automatic features can be included in the design of the installation, so that the plant can be operated with the minimum amount of labor per unit of output. In other words, the labor can be used as efficiently in a medium sized plant of this type as the higher grade labor is used in a much larger condensing plant.

When the plant can be so located as to handle a group of buildings of a diversified character, such, for instance, as a department store, a hotel, a theatre, an office building, and a manufacturing plant, the diversity factor of the steam load will be such that the resultant load on the plant will have only a comparatively small variation.

The type of apparatus installed in a plant of this character, as pointed out in Mr. Parker's remarks, will be comparatively simple and inexpensive. Complicated condensing apparatus will not be required, and there will be a corresponding saving in operating expense, due not only to decreased interest and depreciation charges, but to decreased repairs and supplies. With a plant of this character installed in the business district, where 250-volt direct current distributing systems are used, the high installation cost of a feeder from the distant central station is done away with, and the accompanying line losses saved. In estimating on a recent proposal I found that the approximate cost of installing a 500-h.p. non-condensing plant under such conditions was $25,000; while the cost of a duplicate plant at the central station about one-half mile away, together with the feeder cables, amounted to $94,000. Under these conditions the total operating cost and fixed charges of the non-condensing station per year was $22,590, and of the condensing station and distributing system was $25,790. The fixed charges in each case were $3,050 and $13,250.

These decentralized plants effect the distribution charges in two ways; first, the steam distributing cost; and second, the electrical distributing cost.

The advantages accruing under the heading of steam distributing costs are as follows:

1. Cost of distributing system is less, consequently fixed charges depreciation charges, and repairs are less.
2. Better distribution and better service can be given, as the distance to which steam is transmitted will not be great.
3. Condensation in the distributing system will be less, and the amount of condensed water in the mains which has to be taken care of will be correspondingly less.
4. The system as a whole can be made more flexible by means of tie lines between the different stations, or between the different distributing mains.

The attitude of the customer toward the use of steam can be decidedly influenced, due to the fact that the steam is generated in close proximity to the point at which it is required, rather than being generated at some distant point and transmitted with consequent loss of temperature and increased percentage of moisture in the steam.

The electrical distributing cost is greatly decreased as pointed out above, due to the elimination of expensive transmission lines, expensive generating units, etc.

The operation of plants of this character will enable the central

station company to operate certain of its plants under those conditions which Mr. Main has found to be most economical for textile mills, *i.e.*, use can be made of all the waste products of the plant. I think that the manufacturer can be shown that the value of power and of these waste products to him are much more important than the five per cent value given by Mr. Main. If the cost of power is five per cent of the value of the product, this value being necessarily the selling price, then under average manufacturing conditions the factory cost of the product will not be more than 50 per cent of this selling price, and the power would then become 10 per cent of the factory cost. Furthermore, the cost of raw material entering into the product would probably form at least 50 per cent of the factory cost, and therefore the power forms 20 per cent of the manufacturing cost. Any economy which the manufacturer can make in his cost of power will, therefore, be an important item in his total cost of manufacture. When the central station is in a position to supply the manufacturer with all his requisite power, heat, and light, it can effect economies for him which would otherwise be absolutely impossible.

Referring to Mr. Parker's remarks in regard to the central station companies securing large business, it should be noted that they have not only been hampered in this, but that the profits which they could make from such a transaction have been limited to the profits accruing from the sale of power alone. When these large users can be supplied with the necessary steam, an additional source of profit will be introduced; and whereas the central station may have formerly been carrying a load of this character purely for its sentimental and advertising value, when the heat is supplied in addition, the load will become a profitable one.

In closing, I would like to point out one further advantage which the central station company has in handling business of this character. When a given manufacturer, whom we may call *A*, happens to be operating under conditions such that the exhaust steam from the generating apparatus required to furnish him his necessary light and power is just sufficient to give him the necessary heat and low pressure steam for industrial purposes, he will be operating under his most economical conditions, *i.e.*, the ratio between his light and power load and his heating load is one. His neighbor *B* may be operating under conditions such that this ratio is one-half; another neighbor, *C*, under conditions such that this ratio is $1\frac{1}{2}$. The central station can combine these loads, furnish *A* with his total requirements at his old cost, or somewhat less, and make a considerable saving for both *B* and *C*. In this way, by using a sliding rate which will vary with the steam consumption and the ratio, the manufacturer will be enabled to effect an economy for himself by so arranging his processes of manufacture, etc., as to bring about the most economical operating condition for the central station.

Albert L. Pearson: Regarding motors, I agree in general with Mr. Nye as to the requirements which he has set forth for an induction motor, but feel that one or two points should be given further consideration.

The motor should have a high efficiency, particularly in installations where power is purchased. One per cent difference on a group of ten 100-h.p. machines means 10 h.p., the value of which is an appreciable amount to be added to or deducted from the power bill.

The power factor should be as high as possible, as the voltage regulation of the system is better, and in the case of a large installation considerable saving in copper may be made. An installation of induction motors, recently completed, shows one of the values of high power factor. The power company requires this to be maintained at 90 per cent at its measuring instruments; for anything under this it makes quite an additional charge. In this particular case a rotary condenser is used. Such a machine is fairly desirable provided about 70 per cent of its kilovolt-ampere rating can be turned into mechanical energy. In any case it is a much more troublesome machine than an induction motor, owing to complications of exciter, methods of starting, etc. The curves of efficiency and power factor should be as flat as possible to ensure the most economical operation at all loads, say from 50 per cent to 125 per cent.

The slip, or difference between synchronous and full load speed, should be small to insure, as nearly as possible, constant speed at the machines at all times. This is of special value in textile plants where one motor is used for driving four spinning frames, and in group drives for looms where close speed regulation is not only desirable but often necessary. This same thing applies to a group drive for spinning frames, but probably is not of so much importance as for the four-frame drives. In the case of individual drives this does not count for so much, as the driving gear will be arranged to meet the full-load speed of the motor.

The air gap should be reasonably large so that the motor will require a minimum amount of attention at this point. A small gap, unless carefully watched, is very apt to cause considerable annoyance from rubbing. The ventilation should be good and the ducts, etc., so arranged as to facilitate cleaning. It is desirable to have motors waterproof and the terminals enclosed, for such places as opening and picker rooms, so that all of the contents of a machine may be run out in case of fire.

In textile plants, an overload capacity greater than the standard two-hour rating is not necessary. The cost of a rating of 25 per cent overload continuously is an unnecessary investment. Unless the design is such that efficiency and power factor are their best at 80 per cent of their maximum rating, the point of ordinary operation, there will be a continuous and unnecessary loss.

Regarding the application of motors, there is no question as

to the advantages resulting from individual drives, such as cleanliness from absence of overhead belting and shafting, improvement in illumination, decrease in cost of power, etc. In equipping a plant with electrical drives care should be taken that it is not " overmotored " as such a condition is sure to result in poor voltage regulation and generally unsatisfactory operation. It is often desirable to make tests after installing motors to make sure that proper machines have been selected. This applies more to the equipping of old plants where the power required is often questionable, than to new installations.

The power supply for industrial plants should never be at less than 550 volts, three-phase, 60 cycles, and very satisfactory results are being obtained from 2,080-volt motors above 20- or 25-h.p. sizes. Possibly, in the case of individual drives, where motors smaller than one horse power are used, better results may be obtained from 220 volts.

In a motor-driven plant the wiring takes the place of shafting in a mechanically driven one. This should be installed in a thoroughly first-class manner, protected from injury and so arranged that the voltage at the motor will never be lower than that at which it is rated. Fuses should never be used except on very small sizes of motors. Air-break switches should never be used. Oil switches should be as simple as possible. Current-carrying parts should be liberal, and contacts so arranged as to be easily renewed.

The first cost of motors and starting devices is too often the first consideration, rather than reliability and future operating costs. While the first cost of equipping a textile plant with motor drive may be more than for direct mechanical drive from a steam engine, this is more than offset by the reduced cost of maintenance and the convenience in operation. This is true for synchronous motors as well as induction motors, for a large number of mills in the South have been equipped with these machines using a rope drive the same as for a steam engine.

H. D. James (by letter): The papers this evening discuss the development of electric power for industrial purposes, but have very little to say about the adaptation of this power to industrial machinery. For years we have had electrical power available, we have recognized the advantages of a motor drive for smoothing out the load curve; then why is it that we did not long ago develop this market for power?

The writer believes that this development was retarded; first, by the improper application of motors. Attempts were made to utilize any motor for industrial purposes provided it had the proper characteristics for the electrical power supply. Tests were not made to determine the amount and duration of the load. Often the motor was applied without the designing engineers having any knowledge of the conditions under which the motor was to operate.

Second, the commercial controllers available were unsuitable

for the service and few engineers were making a specialty of this design. The few controller engineers were not associated with the men designing the motors so that there was no mutual adjusting of the apparatus to suit industrial conditions, although at that time the railway field was well developed.

Third, central station managers were making little effort to advise their customers what applications were advisable and assisting them to get satisfactory results.

About five years ago systematic efforts were begun to investigate this field. Where motor drives were not satisfactory, tests were made to determine the actual characteristics of the load. The conditions surrounding the motor were noted; the method of connecting the motor to the load was studied. Experiments were made to develop the best method for controlling the motor for each individual application. This led manufacturers to bring out special motors having the proper electrical and mechanical features to suit particular applications, and capable of satisfactory control.

The controller problem, however, shows the most marked development. The hand-operated controllers have been simplified and made more serviceable. A rapidly increasing line of automatic controllers has been placed on the market. We have developed electrical devices to replace the human brain in the operation of motors. The motor has been made to execute a complicated cycle of operation by means of a small master switch or push button. These controllers, although seemingly complicated are remarkably substantial and easily kept in repair.

There are few drives to which an electric motor cannot be applied profitably if the application is made by a competent engineer. Unfortunately, the number of engineers competent to develop new applications of electric motors is limited. This condition of affairs is largely due to the fact that many engineers do not realize the importance of investigating these applications. A few of the large industries have developed a corps of electrical engineers who have given their whole attention to motor applications. These industries have made rapid strides in electrical development, but unfortunately for the central station, these large corporations have their own power plants.

To make the greatest profit on their investment the central stations must investigate motor applications, either by using the experts trained by large motor manufacturers or else by developing their own corps of experts.

Two articles in the February 1910 issue of the *Electric Journal* give instances of each of the above cases. Consulting engineers would do well to retain controller experts capable of devising special apparatus when necessary, or applying standard controllers to special cases with more intelligence than is often displayed. The many cases of dissatisfaction with motors and controllers which have come to the writer's attention during the last few

years, have generally been due to lack of exact information at the time the apparatus was ordered. It is impossible to extend the use of motor drive unless the customer is satisfied. No matter who is to blame for the trouble, the central station is the loser. The elaboration of central station practice and advantages is of no avail unless we have a market for the power, and motor driving is considered by all as a very desirable element of the load.

Begin with the machine the motor drives and work back to the central station. Furnish the customer with power in the form best suited to his uses. If his machinery requires direct current motors, transform your power to direct current; perhaps a synchronous motor will improve your line characteristics. Do not try to " ram an induction motor down his throat " to save your investment in converting apparatus. A failure at one place may prejudice the local trade against the induction motor and prevent its use at another place where it is the best motor for the service. It is not enough to furnish a motor that will turn over. We must use a motor that can be successfully controlled and then see that the customer has the proper control and is instructed how to use it.

C. A. Graves (by letter): Mr. Main states that the chief items of cost in textile mills are material and labor. Such mills, therefore, should locate in or near cities where cheap labor can be obtained instead of locations where cheap power can be obtained. Also the mill owners should welcome every improvement which will give steady uniform power, as this means increased output without increased labor cost.

It has been demonstrated in numerous instances that central station service, because of its more uniform voltage and frequency, has increased the output in various industries. Therefore owners should be willing to pay for the power which enables them to obtain this increased output. Central stations, because of their reserve equipment and duplicate distribution line, can guarantee continuous service, as is done by the Brooklyn and New York companies in their contract with New York City.

Mr. Hale expresses the situation very well when he says that central stations have no cheap unreliable power for sale.

Regarding the question of load factor, textile mills, I am informed, do not run ten hours per day, every working day in the year, but are shut down about two weeks for inventory and repairs and often Saturday afternoons in the summer time. Another point; curve drawing wattmeters which have been installed on the switchboards of various industries show that the hands do not start working until 7:30 and that the best work, or the most power taken is between 10 o'clock and 11 o'clock. After that time, the load gradually falls off until noon. The same thing happens in the afternoon, except that the load seldom goes as high as in the morning. These facts, then, when taken into account, bring the load factor of the mill below that of large central stations.

The basis of figuring cost of power at $33, per kw-hr. of capacity of plant is not an accurate method, as most plants have a capacity larger than their average load, and some few will run overload part of the time. The proper basis is the maximum load.

Let me give an illustration. One of the recent customers of the Brooklyn Edison Company with a 500-h.p. installation, who was selling power to one of his tenants for $50 per h.p-yr., taking the rated horse power of the motors as a basis, found upon installing a wattmeter, that he was receiving 1¼ cents per kw-hr., for the current, besides furnishing motors. Another extreme case which came to my notice was that of a man selling power at $60 per h.p-yr. for a 10-h.p. motor when the wattmeter showed he was charging at the rate of 20 cents per kw-hr. If these tenants had been charged on the basis of their maximum demand and the current consumption, the charges would have been more just. With the accurate measuring instruments used in the sale of electric current, the old terms employed have to be more accurately defined.

J. H. Gardiner (by letter): Mr. Stickney's paper is evidently intended to be but a brief review of the question of industrial lighting and to touch only the salient points of a very comprehensive subject. It contains much excellent information admirably condensed. The recommendation of general, as opposed to strictly local illumination, is undoubtedly correct from both a physiological and a practical standpoint, and accords with the best modern practice.

In the paragraph treating of lamps, however, it seems as though a brief statement in reference to the Nernst glower lamp might well have been made in view of the peculiar adaptability of this type of lamp to industrial lighting. The features which commend it particularly for this work are its ruggedness, the natural downward distribution of the unit, thus obviating the necessity of reflecting glassware which is always troublesome in an industrial establishment; and most important of all, the low maintenance cost. Maintenance cost becomes the preponderating factor in the total, where the cost of electrical energy is as low as in the case of large industrial installations, and is often the determining one when the choice of high efficiency systems is considered.

H. D. Jackson (by letter): Mr. Hales' paper was entirely from the central station man's point of view, and does not take into consideration the conditions governing power cost in most industrial plants. In the first place, there is no inherent reason why an industrial power plant of fair size should not produce power approximately as cheap as the central station even of large size. The power plant of an industrial establishment can, if necessary, be built with all of the refinements used in the central station, and the operating cost of the plant made very low, nearly as low as the central station, the only difference being

the slight gain in economy of large units over moderate sized units, so that as far as operating expenses go, there is no reason why the smaller plant should suffer materially in comparison with the larger.

As a rule, the fixed charges against the industrial plant would not be greater than against the central plant, as the industrial plant would not be duplicated, whereas the central station plant would have to use extra apparatus in order to preserve continuity of service. This being the case, the cost of power including all charges, fixed and operating, of the two plants situated in the same locality and under the same conditions, would not vary materially.

The above is based on both plants being operated under the same conditions as regards load factor. It is a fact, however, that the central station load factor is very much lower than that of the industrial plant, and the load of the central station far more fluctuating. It is well recognized that a low power factor or a fluctuating load increases to a considerable extent the power cost. This being the case, the difference in the power cost between the two stations would be materially diminished. In some cases this may be to a certain extent offset by the shutting-down period of the industrial plant. This, however, would not influence conditions to a very great extent, as the central station has periods of this character also, although shorter in duration and not complete shutdowns.

The industrial plant is not as a rule as well located for producing power as the central station, so that an increase to the power cost must be made due to increased cost of fuel, etc., in the industrial plant's location. On the other hand, when the total cost of power at the industrial plant switchboard is figured, that is the end of the power cost when generated by the plant itself; whereas this point at the central station is only the first step. The power in this case has yet to be delivered to the customer. According to most central station men, the cost of delivering the power to the customer, metering, billing, etc., is equal to or greater than the cost of production. This being the case and the difference in cost of power slight if plants are built along the same lines as regards refinement, the central station would find it impossible to *deliver* power at the same price the plant could produce it for.

Mr. Hale speaks of the insurance factor of the central station. In order to insure continuity of service, the central station must have not only spare apparatus, but also duplicate lines for distribution—otherwise the power is no more certain than that of the industrial plant. To use an old phrase: "A chain is no stronger than its weakest link", and the single line distributing system is in this case the weak link, which is quite as apt to fail as the high grade unit in the industrial plant, so that the insurance factor of the central station exists only in the imagination. The failure of a unit in the industrial plant affects but that

plant. The failure of the central station in either line or plant may affect many plants.

In order to sell power to an industrial plant, the central station must of necessity be able to produce it at a very much reduced cost as compared to the industrial plant; and the costs of distribution, such as maintaining the distributing system, cost of metering, billing, collecting, and other charges incidental to central station service—must be reduced to a minimum and the cost of power as delivered to the customer has to include all of these items. The cost of power in an industrial plant consists of all of the items incident to the production of that power, but has absolutely nothing to do with the costs of distributing it.

So far, we have considered two plants for producing power alone, and no other use of steam has been taken into account. Most industrial plants have use for heat, either to warm the buildings or for manufacturing purposes. If exhaust steam will serve the purpose, this can readily be taken from the engine, under which condition a much less costly plant will be installed, reducing the fixed charge, also reducing the operating charge, as the steam thus used cannot be properly charged up entirely against power, as it would have to be produced in some way if the engines did not exist, nor can the boilers required for this steam be entirely charged up against power, as they would also have to exist for producing steam if power was purchased. Thus the greater the steam required for industrial purposes, the less the cost of power, not only as regards operation, but also in fixed charges.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

REPORT OF THE BOARD OF DIRECTORS FOR THE FISCAL YEAR ENDING APRIL 30, 1910.

The Board of Directors of the American Institute of Electrical Engineers presents herewith for the information of the membership its annual report for the fiscal year ending April 30, 1910. The report shows the financial status of the Institute, and includes brief statements regarding the work accomplished by the various standing and special committees.

The Annual Convention was held at Frontenac, New York, June 28–July 1, 1909. The total registered attendance was 252. Thirty-six professional papers, including the President's annual address were presented and discussed.

The Board of Directors has held 10 regular monthly meetings during the year.

A number of important changes in the policy of the Institute were effected during the year. Among these was the action resulting from the proposed formation of technical sections, the object of the movement being to broaden the work and scope of the Institute so as to cover as far as possible the entire field of electrical engineering. Upon recommendation of the Law Committee, to which the matter was referred, the Board of Directors at its meeting held on November 12, 1909, adopted resolutions authorizing the President to appoint additional special committees, to promote Institute activity in their respective fields, this being determined upon as the best means of meeting the situation.

On January 14, 1910, the Board adopted resolutions authorizing the holding of Institute meetings under the auspices of Sections. The object of these resolutions has already been clearly set forth in an article by President Stillwell printed in the April 1910 PROCEEDINGS. The resolutions were printed in full in the February PROCEEDINGS. In accordance with this action a successful Institute meeting was held in Boston, February 16, 1910. Other important resolutions adopted by the Board on January 14, 1910, related to the publication of informal communications in the Institute PROCEEDINGS. These resolutions were printed in full in the February 1910 issue.

Another important act of the Board during the year was to create wider distinction between the Institute PROCEEDINGS and TRANSACTIONS. This was discussed at the meeting of the Board held on November 12, 1909, at which a resolution was adopted instructing the Meetings and Papers and Editing Committees to select from the PROCEEDINGS for publication in the TRANSACTIONS only such papers and discussions as might be deemed worthy of permanent record and in making such selection no distinction is to be made between papers presented at the Annual Convention or monthly meetings of the Institute and those presented at any meeting of any Institute Section.

Closer relations between the Institute and the Sections and Branches have been established during the year by the action of the Board in authorizing the Secretary to make a tour of the Pacific Coast and arrange to meet as many western members as possible. This tour was most successful, as may be judged by the Secretary's report to President Stillwell, published in the November PROCEEDINGS. In carrying out this policy the Secretary during the year has visited meetings or conferred with groups of members at the following places, in most of which Sections and Branches existed or have since been organized: Seattle, Portland, Oregon; San Francisco; Los Angeles; Salt Lake City; St. Louis; Washington, D. C.; Boston, Mass.; Philadelphia; Urbana, Illinois; Chicago; Ames, Iowa; St Paul; Madison, Wisconsin; Milwaukee; Fort Wayne; Lewis Institute, Chicago; Armour Institute, Chicago; Charlotte, N. C.; and Pittsfield, Mass., involving a total of approximately 17,000 miles of distance travelled.

Sections Committee..—The Sections Committee is able to report very satisfactory progress in the work of the Sections and Branches during the past year, and a healthful state of affairs at the present time.

Two new Sections have been authorized during the year—one at Portland, Oregon, on May 18, 1909, and the other at Milwaukee, Wis., on February 11, 1910. The Milwaukee Section is undertaking an important development in Section work by coöperating with a local engineering society and local sections of other national engineering societies in such a manner that the efforts of all of these various engineering bodies shall be combined into a harmonious whole, so far as that particular locality is concerned.

Five new Branches have been organized during the year, as follows:

State University of Iowa, May 18, 1909.
Agricultural and Mechanical College of Texas, November 12, 1909.
Rensselaer Polytechnic Institute, Troy, N. Y., November 12, 1909.
Colorado State Agricultural College, February 11, 1910.
North Carolina College of Agriculture and Mechanic Arts, February 11, 1910.

The following table will serve to show the activities of the Sections and Branches for the past three years:

SECTIONS	For Year Ending		
	May 1, 1908	May 1, 1909	May 1, 1910
Numbers of Sections	21	24	25
Section meetings held	141	169	187
Original papers presented	120	167	178
Attendance	7,476	16,427	16,694
BRANCHES			
Number of Branches	22	26	31
Branch meetings held	143	198	237
Original papers presented	84	158	147
Attendance	4,128	8,443	10,255

Meetings and Papers Committee.—The organization of the Meetings and Papers Committee has been materially changed during the past year by the appointment of the chairmen of the special technical committees to membership on the Meetings and Papers Committee and the enlargement of special committees. A further change has been made in holding the special technical committees responsible through their chairmen for Institute activity in the several branches of electrical science covered by them. It was also decided, early in the year, with the approval of the Board of Directors, to hold Institute meetings in different sections of the country, to encourage and develop interest and activity in the Institute work among the entire membership. The result of these changes in organization and methods has been a gratifying increased activity in the Institute work and the broadening of the scope and influence of the Institute.

During the past year this committee arranged for eight regular meetings, two largely attended special meetings, one at Charlotte and the other at San Francisco, the latter under the auspices of the High-Tension Transmission Committee. An adequate number of interesting papers were presented. These meetings partook of the general character of conventions. Two meetings were also held in coöperation with the American Society of Mechanical Engineers and two additional special meetings were held, one at New York and one at Boston.

Educational Committee.—The work of this committee for the year has consisted principally of arranging the April meeting of the Institute at New York, at which a paper on the subject of "Education for Leadership in Electrical Engineering" was presented by Dr. Samuel Sheldon.

The committee desires to emphasize the fact that the Institute has been more active in giving attention to educational matters than any of the other professional engineering organizations in the United States, and it is believed that this has been an important factor in the development of the Institute.

Electric Lighting Committee.—Regular monthly meetings of the committee have been held during the Institute year and the committee has arranged for the presentation of two papers on the subject of electric lighting at the May 17 meeting. Also, three papers have been obtained by the committee for presentation at the 1910 Convention.

High-Tension Transmission Committee.—An Institute meeting was held under the auspices of this committee on December 16, 1909. The committee also assisted in the Charlotte meeting and arranged for a Pacific Coast meeting of the Institute at San Francisco, California, May 5–7, 1910. Several valuable papers and much interesting discussion were obtained by the committee for presentation at these various meetings.

Industrial Power Committee.—Through the efforts of the committee practically all of the Sections and Branches have devoted one meeting this year to industrial power subjects. The March meeting of the Institute in New York was held under the auspices of the committee, as was also a joint meeting in Boston on February 16, 1910. A meeting was also held in New York on April 12, 1910, in coöperation with the American Society of Mechanical Engineers. An attempt is now being made to

collect the papers on the subject presented before the various Sections, with the idea of publishing them in book form if feasible.

Railway Committee.—The Railway Committee has been active in obtaining papers in its field during the past year. Two Institute meetings, devoted to railway subjects, were held in New York under its auspices, and the committee has arranged for a special meeting to be held in New York on May 27, 1910. The committee has broken considerable new ground and will have several subjects to transmit to next year's committee through the Board of Directors. Among these is a suggestion for a change in policy in the manner of conducting a number of special meetings under the auspices of the Committee next year.

Telegraphy and Telephony Committee.—The meeting of the Institute at New York on February 11, 1910 was held under the auspices of this committee. A paper was presented dealing with modern automatic telephone apparatus.

Editing Committee.— Since May 1, 1909, there have been edited and published 12 numbers of the PROCEEDINGS. The total number of pages contained in these PROCEEDINGS is 2,262. Of this total, 402 pages have appeared in Section I, and 1,860 pages in Section II. Of the 1,860 pages in Section II, 1,257 pages were devoted to technical papers, and 556 pages to discussions. Volume XXVIII of the TRANSACTIONS, consisting of the papers and discussions during the calendar year 1909 and the report of the Board of Directors for the fiscal year ending April 30, 1909, contains 1,572 pages. Volume XXVIII will be issued in two parts. Part I, consisting of 752 pages, will contain the papers and discussions presented between January 1, 1909, and the session of June 29, 1909, at the Frontenac Convention. Part II, consisting of 820 pages, will contain the papers and discussions presented between the session of June 29, 1909 at the Frontenac Convention, and December 31, 1909; also the paper read by Mr. H. G. Stott before the Toronto Section on December 18, 1908.

From May 1, 1909 to April 30, 1910 there have been published in full in the PROCEEDINGS five papers read before various Sections and Branches; in addition to four abstracts of such papers, which appeared in Part I of the PROCEEDINGS.

The Editing Committee has gone carefully over the discussions which have been submitted by the Sections and Branches, and has also given its attention to the discussions presented at the New York meetings, to the end that much matter of temporary value has been eliminated and a higher standard of composition as well as material has been maintained. The committee has had under consideration the introduction of metric equivalents in the Institute publications, and has recommended to the Board of Directors that the suggestion of the Standards Committee relating to metric equivalents be given a trial should the Meetings and Papers Committee concur. The Editing Committee also has under consideration the publication of the material presented at joint meetings with other societies.

Standards Committee.—The Standards Committee has held five meetings in New York during the year. The committee has not undertaken a revision of the Standardization Rules this year, but has confined its work in that direction to preparing a separate list of recommended addi-

tions and amendments to the rules. This list is being prepared, and will be submitted at a later date.

The committee has had under consideration a revision of the Institute Copper Wire Table. Prior to undertaking this work, however, the committee consulted the Bureau of Standards concerning the most reliable and advantageous data to employ. The Bureau has taken these questions under consideration.

At its meeting held on December 16, 1909, the committee voted to recommend to the President and Board of Directors of the Institute the adoption of a by-law providing that metric equivalents shall be printed in parentheses after numerical expressions in English units in the Institute publications. This vote was communicated to the President on January 5, 1910, and the recommendation is now being jointly considered in conference between the Editing, and Meetings and Papers Committees.

International Electrotechnical Commission.—The U. S. National Committee of the International Electrotechnical Commission has held five meetings since December last. No convention or unofficial gathering of the Commission has been held during the year, but it is expected that an unofficial gathering will be held in Brussels in the week commencing August 7, 1910.

The following countries are now represented by national committees on the Commission: Argentina, Austria-Hungary, Belgium, Canada, Denmark, France, Germany, Great Britain, Italy, Japan, Mexico, Spain, Sweden, and the United States.

Informal communications have been exchanged with the General Secretary's office in London on the subject of a tentative plan for initiating international standardization in the direction of stationary direct-current generators and motors for continuous-service constant-potential operation.

Informal communications have also been exchanged with members of other national committees in regard to a proposed preliminary list of nine symbols for international adoption in electrical engineering, and the answers received have been very encouraging.

It is hoped that international progress may be made by the Commission in both of the above directions; namely, towards international standardization of machinery, and towards international standardization of symbols used in electrical engineering.

Library Committee.—The complete report of this committee will be printed in the Institute PROCEEDINGS in the near future.

Law Committee.—Various questions have been submitted to this committee for consideration and report within the last year. The most important work of the committee, however, has been in connection with its report on the proposed formation of technical sections of the Institute, and its work in respect to the proposed amendments to the Constitution.

Conservation of Natural Resources Committee.—Owing to the series of investigations which have been in progress in Washington during the greater part of the year, into affairs connected with the conservation of natural resources, the committee deemed it inadvisable to take any active part in connection with conservation until the above mentioned investigations have been completed.

Edison Medal Committee.—On May 18, 1909, the committee awarded to Trygve Jensen, a graduate student of the University of Illinois, the student Diploma of Merit and a cash sum of $150, for his record of research, entitled, "Operation of a 100,000-volt Transformer."

The revised by-laws of the committee, made necessary by the new trust deed, executed on March 26, 1908, were approved by the Board of Directors on May 18, 1909, and are now operative.

The work of the committee during the past year was particularly signalized by the award of the Edison Medal for the first time since the trust creating the medal was established in 1904. The award, for the year 1909, was made on December 16 last to Dr. Elihu Thomson, "For Meritorious Achievement in Electrical Engineering and Arts, as Exemplified in his Contributions Thereto During the Past Thirty Years." The parchment certificate constituting the official notice of the award was presented to Dr. Thomson at the annual dinner of the Institute on February 24, 1910, and the gold medal will be ready for presentation at the annual meeting on May 17.

It is believed that the administrative affairs of the Medal Committee have now been brought into such efficient and working order as to insure hereafter an annual award of the medal.

John Fritz Medal Board of Award.—The John Fritz Medal for 1910 is to be presented to Alfred Noble, for notable achievements as a civil engineer. A special committee has arranged for the presentation, which will be made in the fall of this year. This will be the sixth award of the Medal since its first presentation to Lord Kelvin in 1905.

Board of Examiners.—The Board has held 10 meetings during the year It has considered and reported to the Board of Directors a total of 1,397 applications for Associate election, Student enrolment, and transfer to the grade of Member. A summary of these applications is as follows:

Recommended for election as Associates	814
Recommended for enrolment as Students	507
Recommended for transfer to the grade of Member	47
Not recommended for election as Associates	3
Not recommended for transfer to the grade of Member	26
Total number of applications considered	1,397

The Board has received much assistance during the year from its Local Representatives, of which there are now seven, located in various cities in the United States, Canada, and Mexico.

Membership Committee.—During the year this committee has been active in bringing the advantages of Institute membership to the attention of desirable non-members.

In response to the Committee's general letter of November 8, 1909 requesting the membership to submit names of desirable candidates for admission as Associates, over 1500 names were suggested. All of these were communicated with by letter, accompanied by printed matter regarding the work of the Institute.

The number of applications received from November 1, 1909, at which time the present committee became active to April 30, 1910, is 558 and the total number received during the entire year is 848.

The present total membership and the increase during the past year are indicated below:

	Hon. Mem.	Mem.	Assoc.	Total
Membership, April 30, 1909	1	607	5,792	6,400
Additions:				
New Associates			910	
Transferred		48		
Deductions:				
Died		6	25	
Resigned		2	108	
Dropped		6	482	
Transferred			48	
Membership April 30, 1910	1	641	6,039	6,681

Net increase during the year in membership........................281

The net increase in membership was affected by the recent change in the by-laws. Formerly, a member could be in arrears for three years' dues before being dropped from membership, but under the present by-laws any member who on May 1 is in arrears for one year's dues is dropped as delinquent. This resulted in an unusually large number being dropped on May 1, 1909.

Resignations.—The following Members and Associates have resigned during the year in good standing.

Members.—Robert Hammond, F. M. Pedersen.

Associates.—G. A. Archer, L. T. Arnold, E. R. Avery, J. W. Aylsworth, L. Beauchamp, A. C. Babson, W. A. Baehr, R. Balfour, A. Balsley, W. C. Barnes, M. H. Bentley, H. Binney, C. O. Bourne, J. Broich, C. C. Brown, M. C. Canfield, Eugene Carpenter, S. D. Coffin, F. W. Conn, A. S. Cross, E. H. Cutler, E. W. Cutler, W. B. Dodds, W. A. Drysdale, H. S. Elliott, W. C. Farnell, C. H. Felker, W. S. Finlay, F. H. Foster, Thomas French, Jr., W. H. Glenn, E. W. Goffin, H. de C. Hamilton, W. L. Harraden, W. W. Harris, A. S. Hart, R. Hawxhurst, F. J. Heavens, G. Hellebuck, S. M. Henry, C. W. Hogan, M. B. Holt, E. H. Hoppenstadt, J. H. Hubbs, C. Huper, C. S. Jameson, A. S. Kellogg, A. D. Kenyon, W. A. Kohn, E. Landon, E. C. Laudenberger, M. LeBlanc, A. J. Lowndes, D. Lowson, G. W. MacDonald, H. R. Markel, H. B. Marsh, Hobart Mason, E. M. McCleary, J. H. McConnell, J. L. McKay, W. A. McTaggart, H. S. Meyer, H. M. Migenault, W. H. Miller, N. N. Moneypenny, H. B. Morrell, L. H. Mueller, J. E. Murphy, G. B. Nichols, J. P. O'Donohue, W. N. Parsons, W. W. Patrick, W. J. Peaker, J. Peterson, F. L. Pircher, C. H. Porter, R. H. Read, I. W. Reynolds, C. L. Riley, C. E. Robertson, E. E. Rojahn, C. R. Scott, L. M. Schmidt, H. H. Seaman, C. E. Sedgwick, Sebastian Senstius, G. A. Sherman, S. Aylmer-Small, O. C. Snider, W. M. Stine, H. F. Strickland, A. E. Swan, A. S. Terry, G. C. Thomas, W. H. Tolman, G. A. Tower, L. Van Cott, J. Vandergande, J. H. Warder, F. Wenner, Jefferson Wetzler, R. Wilkander, S. E. Woodbury, L. M. Wright, A. Wunderlich, R. E. Wyllie, L. G. Yochum.

Total resignations, 110.

Deaths.—The following deaths have occurred during the year:

Members.—C. B. Dudley, A. A. Knudson, J. J. Mahoney, J. T. Marshall, Townsend Wolcott.

Associates.—E. T. Alburger, Jr., F. C. Almond, J. W. Bridge, E. A. Briscoe, C. L. Buckingham, W. D. Buckman, H. J. Buddy, A. H. Demrich, T. Hirokawa, S. J. Houston, J. R. Jacobson, G. A. Joffe, A. P. Kennedy, D. Kos, I. Loveridge, W. W. Lyon, Jr., Robert Mitchell, A. W. K. Pierce, C. J. Toerring, J. C. Reilly, Ralph Scott, F. N. Simpson, G. W. Thompson, F. G. Tracy, H. E. Wagganan, C. I. Zimmerman.

Total deaths, 31.

Delinquent.—Dropped as delinquent during the year, 482.

Building Fund.—The amount collected from subscribers during the year was $2,552.15. The interest on the bank balances amounted to $585.25. These items make a total to the credit of the Building Fund during the year, of $3,137.40. A payment of $27,000. on account of the principal of the mortgage, was made during the year.

LAND, BUILDING AND ENDOWMENT FUND.

Receipts.		Disbursements.	
Before appointment of Committee	$ 6,100.00	Paid United Engineering Society, acct. of contract	$ 8,000.00
Collected by Committee	145,881.05	Paid United Engineering Society, acct. of mortgage	126,000.00
Interest on balances	5,967.01	Paid United Engineering Society, acct. of interest	19,529.45
Reimbursement by Institute	9,221.95	Expenses of Committee	10,440.73
		Balance in bank, May 1, 1909	3,199.83
Total	$167,170.01	Total	$167,170.01

RECEIPTS AND DISBURSEMENTS PER YEAR PER MEMBER.

During each fiscal year for the past seven years.

Year	1904	1905	1906	1907	1908	1909	1910
Membership, April 30th, each year	3027	3460	3870	4521	5674	6400	6681
Receipts per Member.	$13.66	$12.32	$12.77	$12.21	$13.01	$13.21	$13.35
Disbursements per Member:	$12.02	$10.72	$10.48	$11.62	$11.73	$10.49	$12.03
Credit Balance per Member	$0.64	$1.60	$2.29	.59	$1.28	2.72	1.32

Finance Committee.—The following correspondence and financial statements form a complete summary of the work of this Committee.

May 17, 1910.

Mr. Lewis B. Stillwell,

President American Institute of Electrical Engineers,

No. 33 West 39th Street, New York City, N. Y.

Dear Sir: In accordance with past practice, your Finance Committee respectfully submits the following annual report:

During the past year the Committee has held monthly meetings, has passed upon the expenditures of the Institute for various purposes, and otherwise has performed the duties prescribed for it in the Constitution and By-Laws. Messrs. Peirce, Struss & Company, the chartered accountants, have audited the Institute books, and attached hereto is their certificate of the Institute's finances.

In company with your Treasurer and a member of the firm of chartered accountants, the Committee has examined the securities held by the Institute, and find them to be as stated in the accountants' report.

It is of interest to call attention to an additional payment of $27,000 towards the liquidation of the Institute indebtedness on the land on which the United Engineering Society's Building stands. By the payment of this sum, we have anticipated our obligations up to 1919, thereby proportionately reducing the annual interest payment.

In closing this report it seems proper to call attention to the fact, that the income for the Institute, estimated for the year in advance, has been exceeded by the actual income, so that even with an increased budget of expenditures by reason of the Institute's extended activities, it has been possible to close the fiscal year with a comfortable surplus.

Respectfully submitted,
CALVERT TOWNLEY,
Chairman Finance Committee.

New York, May 10, 1910.

MR. CALVERT TOWNLEY,
Chairman Committee on Finance.

Dear Sir: In accordance with your instructions, we have audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1910.

The results of this examination are presented in four exhibits, attached hereto, as follows:

Exhibit A. Balance Sheet, April 30, 1910.

Exhibit B. Receipts and Disbursements for general purposes for year ended April 30, 1910.

Exhibit C. Receipts and Donations for designated purposes also expenditures for year ended April 30, 1910.

Exhibit D. Condensed Cash Statement.

We beg to present attached hereto our certificate to the aforesaid exhibits.

Yours very truly,
(Signed) PEIRCE, STRUSS & CO.
Certified Public Accountants.

New York, May 10, 1910.

MR. CALVERT TOWNLEY,
Chairman, Committee on Finance.

Dear Sir: Having audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1910, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of April 30, 1910, and that the accompanying statements of Cash Receipts and Disbursements are correct.

(Signed) PEIRCE, STRUSS & CO.
Certified Public Accountants.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Balance Sheet, April 30, 1910.

Exhibit A.

Assets.

Cash:		
Land, Building and Endowment Fund	$3,199.83	
General Library fund	258.04	
Compounded Membership fund......	5,018.24	
Mailloux fund, principal...........	1,000.00	
		$9,476.11
General Cash in bank	17,802.98	
Mailloux fund, interest..............	60.35	
Weaver donation....	65.44	
International Elec. Congress of St. Louis Library fund, interest.........	154.92	
Total cash deposit..	18,083.69	
Secretary's petty cash on hand.....	750.00	
		18,833.69
Land, Building and Endowment fund, accrued interest..	70.37	
General Library fund accrued interest..	2.69	
Compounded Membership fund accrued interest.....	58.31	
International Electrical Congress of St. Louis, 1904, Library Fund accrued interest....	45.00	
		176.37
International Electrical Congress of St. Louis 1904, Library Fund, Bonds...........	2,268.00	
		2,268.00
New York City 4½% Gold Bonds......	30,000.00	
Premium on bonds.	1,952.50	
		31,952.50
Westinghouse Electric & Mfg. Co's. stock............		50.00
Equity in Engineering Societies Building (25 to 33 West 39th St.).........	353,346.61	
One-third cost of land (25 to 33 West 39th St.)....	180,000.00	
		533,346.61
Library Volumes and Fixtures.........	27,309.14	
Transactions.......	7,446.25	
Office Furniture and Fixtures.........	6,692.20	
Works of Art, Paintings, etc.........	2,543.60	
Badges............	517.05	
		44,508.24
Accounts Receivable:		
Members for current dues.............	660.00	
Members for past dues, suspense account...........	7,794.00	
Members for entrance fees.............	325.00	
Miscellaneous.......	494.18	
For Advertising....	2,356.25	
Accrued interest on Bonds...........	675.00	
Accrued interest on bank balance.....	219.25	
		12,523.68
Total Assets......		$653,135.20

Liabilities and Surplus.

Funds:		
Land, Building and Endowment Fund	$3,270.20	
General Library Fund............	260.73	
Compounded Membership Fund.....	5,076.55	
Mailloux Fund......	1,060.35	
International Electrical Congress of St. Louis 1904, Library Fund:		
Bonds...........	2,268.00	
Cash, on deposit.	154.92	
Accrued Interest.	45.00	
		$12,135.75
Reserve, for Furniture and Fixtures.		1,568.78
Accounts payable, subject to approval by the Finance Committee.......		4,558.34
United Engineering Society (for cost of land)..........		54,000.00
Total Liabilities..		72,262.87
Surplus:		
In Cash............	17,802.98	
New York City bonds	31,952.50	
In property and accounts receivable.	531,116.85	
		580,872.33
Total Liabilities and surplus.		$653,135.20

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Receipts and Disbursements for General Purposes for Year Ended April 30, 1910.

Exhibit B.

Receipts.

Entrance Fees	$4,265.00	
Current Dues	59,943.37	
Past Dues	5,541.75	
Advance Dues	112.50	
Students Dues	3,984.00	
Transfer Fees	500.00	
Badges	1,875.00	
		76,221.62
Sales, Transactions, etc.	1,477.43	
Subscriptions, Proceedings	1,669.57	
Advertising	7,727.00	
Binding	136.10	
Exchange	26.74	
Interest:		
Bonds	1,350.00	
Bank Balance	591.42	
		12,978.26
		$89,199.88

Disbursements.

Stationery and Printing	$2,924.98	
Postage	2,466.81	
General Expenses	2,350.67	
Meeting Expenses	3,318.54	
Section Meetings	7,257.99	
Badges purchased	1,694.74	
Salaries	9,915.50	
Interest on Mtge	3,240.00	
Bibliography	741.18	
Office Furniture	497.65	
Advertising Expense	3,267.38	
Year Book and Catalogue	2,616.16	
Express	466.47	
Miscellaneous	20.70	
		$40,778.77
Proceedings:		
Printing, paper, binding, engraving	16,096.86	
Salaries	3,400.00	
		19,496.86
Transactions:		
Vol. 27		8,623.46
Vol. 28		2,595.87
Library (including salaries)		3,265.73
United Engineering Society:		
Assessments for office space		5,333.35
Total		80,094.04
Excess Receipts over Disbursements		9,105.84
		$89,199.88

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Receipts and Donations for Designated Purposes, also Expenditures for Year Ended April 30, 1910.

Exhibit C.

Receipts.	
Land, Building and Endowment Fund, Donations, Interest, etc.	$3,137.40
General Library Fund, Interest	6.53
Compounded Membership Fund, Interest	189.54
International Electrical Congress of St. Louis 1904, Library Fund, Donations and interest	115.80
Mailloux Fund, Interest	60.00
Total	$3,509.27
Expenditures.	
Land Building, and Endowment Fund, on account of mortgage	27,000.00
Compounded Membership Fund	526.87
International Electrical Congress of St. Louis 1904 Library Fund	85.60
Special Library account (to be reimbursed)	61.00
Total	$27,673.47

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Condensed Cash Statement.

Exhibit D.

Cash on deposit April 30, 1909	$42,868.16	
Secretary's Petty Cash, April 30, 1909	500.00	
		$43,368.16
Receipts for general purposes, Exhibit " B "	89,199.88	
Receipts for designated purposes, Exhibit " C "	3,509.27	
		92,709.15
		$136,077.31
Disbursements for general purposes Exhibit " B "	80,094.04	
Expenditures for designated purposes, Exhibit " C "	27,673.47	
		107,767.51
Balance on hand April 30, 1910		28,309.80
On deposit for designated purposes, Exhibit " A "	9,476.11	
*On deposit in General cash, Exhibit " A "	18,083.69	
Secretary's Petty Cash, Exhibit " A "	750.00	
		28,309.80
Property acquired during the year, Office Furniture and Fixtures		497.65

*This includes the following unexpended balances:

Mailloux Fund	$60.35
Weaver Donation	65.44
Int. Elec. Congress of St. Louis Library Fund	154.92
	$280.71

Respectfully submitted for the Board of Directors

RALPH W. POPE, Secretary.

New York, May 17, 1910.